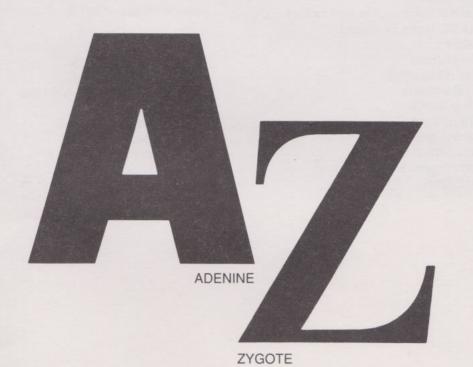
SCIENCE



Course Index

THE SCIENCE FOUNDATION COURSE TEAM

Steve Best (Illustrator)

Geoff Brown (Earth Sciences)

Jim Burge (BBC)

Neil Chalmers (Biology)

Bob Cordell (Biology, General Editor)

Pauline Corfield (Assessment Group and

Summer School Group)
Debbie Crouch (Designer)

Dee Edwards (Earth Sciences; S101 Evaluation)

Graham Farmelo (Chairman)

John Greenwood (Librarian)

Mike Gunton (BBC)

Charles Harding (Chemistry)

Robin Harding (Biology)

Nigel Harris (Earth Sciences, General Editor)

Linda Hodgkinson (Course Coordinator)

David Jackson (BBC)

David Johnson (Chemistry, General Editor)

Tony Jolly (BBC, Series Producer)

Ken Kirby (BBC)

Perry Morley (Editor)

Peter Morrod (Chemistry)

Pam Owen (Illustrator)

Rissa de la Paz (BBC)

Julian Powell (Editor)

David Roberts (Chemistry)

David Robinson (Biology)

Shelagh Ross (Physics, General Editor)

Dick Sharp (Editor)

Ted Smith (BBC)

Margaret Swithenby (Editor)

Nick Watson (BBC)

Dave Williams (Earth Sciences)

Geoff Yarwood (Earth Sciences)

Consultants:

Keith Hodgkinson (Physics)

Judith Metcalfe (Biology)

Pat Murphy (Biology)

Irene Ridge (Biology)

Jonathan Silvertown (Biology)

External assessor: F. J. Vine FRS

Others whose S101 contribution has been of considerable value in the preparation of S102:

Stuart Freake (Physics)

Anna Furth (Biology)

Stephen Hurry (Biology)

Jane Nelson (Chemistry)

Mike Pentz (Chairman and General Editor, S101)

Milo Shott (Physics)

Russell Stannard (Physics)

Steve Swithenby (Physics)

Peggy Varley (Biology)

Kiki Warr (Chemistry)

Chris Wilson (Earth Sciences)

The Open University, Walton Hall, Milton Keynes, MK7 6AA.

First published 1989; reprinted 1992.

Copyright © 1989, 1992 The Open University.

All rights reserved. No part of this work may be reproduced, stored in a retrieval system or transmitted, in any form or by any other means, without permission in writing from the publisher.

Designed by the Graphic Design Group of the Open University.

Filmset by Santype International Limited, Salisbury, Wiltshire, printed in the United Kingdom by Tranby Printers Limited, Willerby, Kingston-upon-Hull.

Further information on Open University Courses may be obtained from the Admissions Office, The Open University, P.O. Box 48, Walton Hall, Milton Keynes, MK7 6AB

varves used to determine, 28-29, 8,

NOTES

1 This index refers to all the material contained in the texts of Units 1 to 32 of S102. The supplementary material (Summer School Laboratory Notebooks, CALCHEM Notes, etc.) is not indexed. For each entry, the page references for each Unit in which the entry appears follow the Unit number, which is printed in bold. Flagged terms are printed in bold. Numbers of Units in which these terms are flagged are denoted by an asterisk. For example, the entry polar solvents, 13-14*, 68; 17-18, 23 tells you that the term polar solvents is flagged in Units 13-14 on page 68, and that it also occurs on page 23 of Units 17-18.

A

A see adenine abbreviated structural formulae, 17-18*, 9, 38, 39 abnormalities, genetic, 20, 20-1 abrasion, 27, 37 absolute dating method, 28-29*, 24,35 absolute zero, 9, 24, 28 absorption of photon see photoelectric effect absorption spectra, 11-12*, 26, 27, 32, 36, 48, 70-1; 31, 3 absorption spectrophotometry, 15, 38 abstract of a report, 4, 29 abyssal plain, 7-8*, 10 acceleration, 3*, 6, 7; 9, 13, 14, 17 due to gravity on Earth, 3, 18, 19, 21, 24-31, 33-6; 5-6, 10 measuring, 3, 24-6 stroboscopic determination of, 3, 26-31 force and, 3, 9-10, 11, 14-15, 20 mass and, 3, 12-13, 23 orbital, 3, 32, 33-4 accelerators, particle, 30, 5; 32, 5, 8-10, 18, 32 linear, 32, 8, 10 circular (synchrotron), 32, 8-9, 40 accretion, planetary, 28-29, 45-50, 57 accuracy and precision, 4, 17-20 accurate measurement, 4*, 18, 19 Acetabularia, 24, 21-2 acetaldehyde, 17-18, 40, 72; 22, 31, 57 acetamide, 17-18, 70 acetate, 17-18, 68, 70, 81 anion, 15, 19, 21, 37 acetic acid (ethanoic acid), 15, 5-6; 17-18, 39; 22, 16, 46, 48, 50, 51, 54 chemical reactions, 17-18, 63, 64, 67-8, 81 equilibrium in, 15, 21-3 formation from ethanol, 17-18,

71 - 2

pH of, 15, 30, 37 smell of 15, 20 weak electrolyte, 15, 19, 25 Acetobacter bacteria, 17-18, 71 acetone, 17-18, 39, 40, 42, 43, 72, 96 acetyl chloride, 17-18, 64 acetyl coenzyme A (acetyl CoA), 22*, 45, 46, 50, 61 see also acetic acid acetylene, 17-18, 37-8, 39, 67 achondrites, 28-29*, 45, 47, 50, 51, 80 achromatic time, 22*, 33, 37, Plate 3 acid, 15*, 4, 5-6, 9 defined, 15, 7 ionic theory and, 15, 6-7 strong, 15, 18, 23, 26 weak, 15, 18, 19, 20, 24 see also carboxylic acids; nucleic acids acid chlorides, 17-18, 64, 67, 69, 70, 74, 76 acid dissociation constant, 15*, 23 acid rain, 15*, 30-1, 32, 33; 25, 30-1, 32 acid strength, 15*, 19 acquired characteristics, 19*, 12, 15 acrylic, 17-18, 78, 86, Plate 9a actinides, 13-14*, 39, 41 activated complex, 16*, 23 activation energy, 16*, 21, 22-5, 26, 27, 28, 29; 26, 10, 18 and enzyme catalysis, 22, 26 activation of enzymes, 22, 58 active site, 22*, 26, 27, 36; 26, 10, 17, 18 active transport, 22*, 9, 10 adaptation, 19*, 13, 14, 15, 36-7; 22, 20, 29; 26, 6 relationship between structure and function, 19, 13-14; 22, 20 survival and, 19, 15-20 addition polymers/polymerization, 17-18*, 78, 79-81, 90, 96 addition reactions, 17-18*, 73, 74 adenine (A), 17-18, 89; 24*, 10, 11-12 adenosine disphosphate (ADP), 22*, 11, 12; 23, 4; 24, 29 adenosine triphosphate (ATP), 22*, 11, 12, 13, 62; 23, 4; 24, 29, 34 production in catabolism of carbohydrates, 22, 42, 43, 44, 48, 49, 51, 52, 53, 54, 55, 57 production in photosynthesis, 22, 63, 64 in regulation of catabolism, 22, 59 ADP see adenosine diphosphate adrenal cortex, 23*, 36 adrenal glands, 23*, 36, 37 adrenalin, 23*, 27, 28, 31, 32, 36, 37; 26, 18 advantage, 19, 37 aerobic catabolism, 22, 47 balancing equation for glucose catabolism, 22, 48-54 aerobic respiration, 22*, 10 aerosols, 17-18, 15, 16, 78 Africa, 7-8, 10 crustal plate, 7-8, 54, 55, 60, 61 rifts, 7-8, 29 sediments, 7–8, 29 fossils, 7–8, 20, 29 aftershocks, 5-6*, 19 age of Earth, 28-29, 4, 35-7 fossils used to determine, 28-29, 8, 11, 13, 24

13 see also dating; time age of rocks see rocks age of Universe, 32, 44-5 agriculture and production ecology, 25, 10-11, 18 Agrostis tenuis (common bent grass): copper tolerance, 21, 9, 10 AIDS, 19, 3, 9 air gases of discovered, 13-14, 74 liquefaction of, 13-14, 75 oxygen in, 23, 4, 8, 10 temperature and density, sound waves and, 10, 4-6 see also atmosphere alanine (Ala), 17-18, 60, 92, 93; 22, 15, 21, 45; 24, 36 alarm pheromones, 17-18, 48, 49, 51, albedo, 28-29, 78 alcohols, 17-18*, 9, 21, 22, 23, 25, 63, chemical reactions, 17-18, 63, 64, 67-8, 71-2, 74, 81, 82 formation, 17-18, 73, 75 homologous series, 17-18, 19-22 physical properties, 17-18, 10-11, 13, 22-4 alcohol dehydrogenase, 22*, 31, 57 aldehydes, 17-18*, 39, 40, 70 chemical reactions, 17-18, 72-3 isomerism with ketones, 17-18, 42 Aldrin, 17-18, 47 Alexandria scientific school at, 2, 14 in size of Earth measurement, 2, 15-16, 18-20 algae excessive growth of, 25, 27, 33 alginic acid, 22, 17 alkali metals, 13-14*, 25, 30, 59, 60, 72 - 3, 75discovery of, 13-14, 74 alkalinity, 26, 11, 18 alkanals see aldehydes alkanamines see alkylamines alkanes, 17-18*, 19 bonding and molecular structure, 17-18, 7-8, 27 homologous series, 17-18, 18-19, physical properties, 17-18, 10-11, 22 - 3alkanols see alcohols alkanones see ketones alkenes, 17-18*, 38, 39 bonding and molecular structure, 17-18, 37 chemical reactions, 17-18, 38, 73, 74 geometric isomerism, 17-18, 43-5 unsaturation, 17-18, 37-9 alkylamines, 17-18*, 21, 22, 69, 70 alkyl group, 17-18*, 21 alkynes, 17-18*, 38, 39 bonding and molecular structure, 17-18, 38 chemical reactions, 17-18, 73 unsaturation, 17-18, 37-9 alleles, 20*, 25, 50, 52; 22, 5, 6, 23; 26, 5, 6, 16

alleles (continued) dominant and recessive, 20, 27, 30, 38, 41 independent assortment of, 20, 35-6, 38, 44 multiple 20, 52 see also genes; genetic variability alloy, 13-14*, 69; 28-29*, 43, 44 see also nickel-iron α-decay, 11-12*, 19; 31*, 28, 29, 32-3, 36, 37 α-1,4 glycosidic bonds, 22, 18; 26, 18 α-oxoglutaric acid, 22, 45 α-particle, 11–12*, 13, 14–15, 18, 23; 31, 34, 38 scattering, 11-12, 13-18; 32, 6, 24 aluminium in alloy, 13-14, 69 chemical bonding, 13-14, 65, 69 in oceans, 28-29, 59 in rocks, 27, 6, 9, 11, 15, 20, 22-3; 28-29, 46 alveoli, 23*, 9, 10, 11, 13, 14, 24 amber, 28-29, 6 American song sparrow, races of, 21, 25 amethyst, 27, Plate 5 amides, 17-18*, 69, 70 formation of, 17-18, 74, 81, 97 see also polyamides amines bonding and molecular structure, 17-18, 9 chemical reactions of, 17-18, 74, 76, 81, 90 see also alkylamines amino acids, 17-18*, 60, 61, 69; 19, 8, 10; 22, 7, 15, 21, 43, 64; 24, 9, 12, 32-3; 26, 8, 9, 10, 17, 18 as building blocks of proteins, 17-18, 60, 69, 88-9; 22, 21 catabolism of, 22, 61; 23, 23 formation on primitive Earth, 17-18, 92-4; 28-29, 62, 69 genetic code and, 24, 35-7 ionization of, 22, 21, 23, 67 mutation and, 24, 40, 41 polymerization, 17-18, 88-9; 22, protein synthesis and, 24, 23, 27-9, 31, 34, 38 transport of, 23, 11 amino acid residues, 17-18*, 88; 22, 21-23 amino acid-tRNA complex, 24*, 31, 32 amino group, 17-18*, 20 6-aminohexanoic acid, 17-18, 82 2-aminopropane, 17-18, 70 ammonia, 13-14, 56, 60; 15, 5; 22, 26, 61, 67 dissolved, as base, 15, 9, 10 excretion of, 23, 23 in nitrogen cycle, 25, 25-6, 27-9, 31 pH of, 15, 30 in primordial atmosphere, 17-18, 91-2; **28-29**, 57, 60, 62 as refrigerant, 17-18, 14 synthesis of, 16, 30-2 ammonites, 28-29*, 9, 10, 17, 68 ammonium ions, 22, 61, 67; 25, 25-6, 27 - 9, 31amoebae, 19, 6, 9

amoebic dysentery, 19, 6 amount of substance, 13-14*, 17, 18 ampere (amp), 9*, 34, 35 Ampère, André-Marie, 9, 34 amphibians, 28-29, 11-12, 67, 70 amphiboles, 27, 9, 10, 15, 16, 32 amplitude of a wave, 5-6*, 24, 25; 10*, 11, 16, 20, 22-3, 24 amylase, 22*, 18; 26, 9, 10, 18 salivary, properties of, 22, 33-5, 37 amylopectin, 22*, 17, 18-19 amylose, 22*, 17, 18-19, 33, 35; 26, 10, 18 anabolism, 22*, 9, 10, 64 see also biosynthesis; metabolism anaemia, sickle-cell, 21, 16-19; 22, 6, 23; 24, 40 anaerobic catabolism, 22, 57 anaerobic organisms, 28-29, 63-4 anaerobic respiration, 22*, 57 anaesthetics, 17-18, 4, 35, 78 anaphase in meiosis, 20, 13, 15, 16, 20, 21; 26, 5, 15 compared with mitosis, 20, 47, 48, Andean-type margin see ocean/ continent Anderson, Carl, 32, 14 andesites, 7-8*, 72, 79; 27, 26, Plate 11 composition of, 27, 9, 26 formation of, 27, 20, 24-9, 52-3 angle, epicentral, 5-6, 61, 62, 63, 64-5, 68-9, 74 angle of incidence, 5-6*, 33, 34-5 critical, 5-6, 35, 72 angle of reflection, 5-6*, 34 angle of refraction, 5-6*, 33, 34 critical, 5-6, 72-3 angles measurement of, 2, 18, 19, 20, 22-3, 27 of triangle, 2, 27, 32 angular measure, 2, 18 angular size, 2*, 22, 23-4, 28-9 aniline, 17-18, 41 animals, 19, 4-5 adaptation by, 19, 13, 14 cells of, 19, 5-8; 22, 38, 39; 26, 4, 15 classification, 21, 27, 29-32 genetic variability, 21, 13, 14, 15 speciation, 21, 22-6 see also carnivores; herbivores; heterotrophs; individual animal names anions, 13–14*, 46–7, 48, 49–50, 57, 72; 22, 14 see also bicarbonates; nitrates; phosphates; sulphates anomalies see gravity anomalies; magnetic anomalies Anopheles mosquito, malaria transmitted by, 21, 18 antagonistic action of nervous systems, 23, 34 Antarctic ozone hole, 17-18, 16, Plate 5 antibaryons, 32, 22, 26 anticodon, 24*, 31, 33 antileptons, 32, 14-16, 34-5 antimatter see antiparticles antimony, 13-14, 69; 28-29, 46 antineutrino, 31, 30, 36; 32, 14-16,

28-9, 35, 41

antiparticles, 32*, 12, 14 of gauge bosons, 32, 39 of hadrons, 32, 22, 26 of leptons, 32, 14-16, 28-9, 34-5 of quarks, 32, 25-9, 33 antiquarks, 32, 25-9, 33 anus, 26, 10 aorta, 23*, 14, Plate 9 apes, 21, 31 aphids, 17-18, 49 apparent polar wandering, 5-6*, 84-6; **7–8**, 27, 58 apparent size of Sun and Moon, 1, 17, 22, 24 aquatic ecosystems communities in freshwater pond, 25, 4-5 energy flow in, 25, 16-17 polluted, 25, 29, 30, 32 see also oceans aquatic food chain and web, 25, 12, 16-17; 26, 12, 18-19 aqueous solution, 13-14*, 43 arc of circle, 2, 18, 19-20, 22-3, 30 Archimedes' principle, 7-8*, 30, 31; 27, 12 Arduino, Giovanni, 28-29, 14-15 arginine (Arg), 22, 21; 24, 36 argon, 11-12, 5 in atmosphere, 28-29, 52, 55, 56, 57, 60 chemical inertness, 13-14, 58, 65 electronic configuration, 11-12, 60 first ionization energy, 11-12, 64 isotopes, 28-29, 30, 31 photoelectron spectrum, 11-12, 52, Aristarchus, 2, 26, 27, 31, 46 Aristotle, 2, 14 Arrhenius, Svante, 15, 7 Arrhenius definitions, 15*, 6, 9-10 arteries, 23*, 12, 13, 14, 33 chemoreceptors in, 23, 33 pulmonary artery, 23, 13 arterioles, 23*, 12, 14, 19-20, 33, 35 arthropods, 21, 29-30, 32; 28-29, 65 artificial elements discovered, 13-14, 75 ash, volcanic, 27, 20; 28-29, 55 asparagine (Asn), 24, 36, 40, 41 aspartic acid (Asp), 17-18, 92; 22, 21, 23, 30; 24, 36 assay, enzyme, 22, 32, 33-5, 37 assimilation, 22*, 8; 25*, 7, 13, 14, 18; 26, 12 asteroids, 28-29*, 39, 41, 48 asthenosphere, 7-8*, 33, 76, 78, 79 Atlantic Ocean, 7-8, 10, 12, 29, 49, 54, 58 continental drift theory and, 7-8, 17, 18, 20, 28-9 formation, 7-8, 38 fracture zones, 7-8, 54 'proto-', 7-8, 57 ridges, 7-8, 29, 54, 58 see also Mid-Atlantic Ridge spreading rate, 7-8, 46-7 atmosphere biogeochemical cycles and 25, 20 - 29energy flow in, 28-29, 71, 72 origin of, 28-29, 52-8, 60-1 early, 28-29, 62-3, 69 evolution of, 28-29, 57-8, 61

atmosphere (continued) volcanic gases in, 28-29, 55-6, see also air and under oxygen atoms, 11-12*, 3, 5-12 constituents of see fundamental particles Heisenberg's uncertainty principle applied to, 30, 29-31 and internal energy, 9, 27-9, 30 random motion of, 9, 27-9, 30 size of, 11-12, 6-7, 11 time (after Big Bang) when formed, 32, 44-45 see also atomic energy; atomic nucleus atomic bombs, 9, 5; 11-12, 23; 13-14, 41 energy from, 9, 12 atomic energy levels, 31, 3-4, 11-17, 21-2 advanced atomic models, 31, 15-16 hydrogen atom model, 31, 4, 11-14 see also atomic nucleus; energy atomic mass see relative atomic mass atomic nucleus/nuclei, 11-12, 14, 15, 16, 18; 31, 3-4, 17-28 binding energies, 31, 23, 25, 27, 29, contents of, 31, 17-19, 27 energy levels, 31, 21-2, 27 excited, 31, 31, 32, 36 and fundamental particles, 32, 29, 42, 44 masses and Einstein's equation, 31, 24, 26-7 strong interaction of constituents, 31, 19-20, 27 time (after Big Bang) when formed, 32, 44-5 see also nuclear fission; nuclear fusion; radioactive decays of atomic number, Z, 11–12*, 16, 17, 18, 24, 42, 72; 13–14, 29, 58, 65, 76, 79; 31*, 17, 18, 19 first ionization energy, 11-12, 62, 63-6 atomic spectra, 11-12*, 24, 25-37, 70 - 1interpretation of, 11-12, 47-51 line spectra, 11-12, 24, 26, 27-9, 30, 70-1 Lyman series, 11-12, 30-3, 35, 47 atomic spectroscopy, 13-14, 75 atomic structure of minerals, 27, 7-9, 11, 16, 32, 44 ATP see adenosine triphosphate atria, 23*, 12, 13, 14, 34, Plate 9 autoclave, 17-18, 97 autotrophs, 22*, 8, 9, 10-11, 12, 38, 39, 61, 65; 23, 4; 26, 12, 18; 28-29, 63, 64 biogeochemical cycles and, 25, 22, 25-6, 28, 31 production ecology and, 25, 6-10, 11-12, 18 average, calculating an, 4, 19, 26 average bond energies, 16*, 12, 13, 18 Avogadro's constant (NA), 13-14*, 16 Avogadro's hypothesis, 16, 31 Avogadro's law, 13-14*, 18, 19 axes of a graph, 2*, 37, 38, 39; 4, 11,

13-15, 24 axial dipole, 5-6, 47, 48, 55 axial modulus, 5–6*, 30, 31, 32, 60, 81 axial rift, 7–8*, 11, 15, 29, 40, 64 axially geocentric dipole, 5-6*, 47, 48, axis of rotation of an object, 1*, 24; of the Earth, 1, 25, 30-1, 40-1, 43; 5-6, 48, 70, 83-4 geometric variations in, 28-29, axis of spin of an object, 1*, 24

B Bacon, Francis, 7-8, 17 bacteria, 19, 9, 11 biogeochemical cycles and, 25, 26, 28, 29, 31, 32 blue-green, 21, 29; 28-29, 54, 55, 58, 61, 63, 65, 69 as factories for human proteins, 24, food chains and food webs and, 25, 11, 13 transformation, 24, 5 viral infection of, 24, 6-7, 8 Bakelite, 17-18, 84 balance in the environment, 26, 14 balanced carbon cycle, 25, 23 balanced (chemical) equations, 11-12*, 8; 13-14, 19-21; 22, 48-54 balanced forces, 3*, 10 balanced polymorphism, 21*, 16-18, 19, 22 Balanus balanoides (barnacle), 25, 57, 58 Baldwin, Ernest, 22, 40 Balmer series, 11-12, 28-9, 47 bananas (Musa esculenta), 25, 34-5, banded ironstone formations (BIF), 28-29*, 53, 59, 60, 63-4, 65, 78 bar magnets, magnetic forces, 5-6, 42-3 poles and field, 5-6, 45-6 Bardeen, John, 30, 34 barnacles, 25, 57-8 baryons, 32*, 22, 26-7 baryon number, 32*, 20 conservation, 32, 20-1 of gauge bosons, 32, 21, 39 of hadrons, 32, 20, 21-2, 23-4, 27, 32 of leptons, 32, 21 of quarks, 32, 26, 36 Baryonyx walkeri (carnivorous dinosaur), 28-29, 81 basalt/basaltic rock, 5-6*, 8, 77, 79, Plates 11 and 12; 27*, 11, Plate 3; 28-29, 4, 42, 47, 55 composition of, 27, 9, 11, 18, 21-3 formation of, 27, 19-21, 24, 25, 29 plate margins and, 7-8, 63, 64, 72, 73, 78 dykes, 7-8, 63, 64, 65, 68, 78; 28-9, 32, 33 pillow lavas, 7-8, 63, 65, 78

bases (chemistry), 15*, 4, 5-6, 9

ionic theory and, 15, 6-7

defined, 15, 7

strong, 15, 18 bases (biology), 24*, 10, 11-13, 21, 24; 26, 8, 18 complementary, 24, 11, 12, 25 genetic code and, 24, 35-7, 38 mutation and, 24, 40-1; 26, 8, 17 non-coding, 24, 45, 47 protein synthesis and, 24, 22, 24-7, 31, 32, 33 see also adenine; cytosine; guanine; uracil; paired bases; thymine base-pairing rules, 24*, 11, 25 Bateson, William, 20, 30-1 batholith, 7-8*, 70, 72 BCF (bromochlorodifluoromethane), 17-18, 15, Plate 4 beaches, 27, 33, 36, 37, 38 beauty see bottomness BEBC (Big European Bubble Chamber), 32, 11 bed, 28-29*, 16, 24 bedding, graded, 28-29, 8, 14 dune, fossil, 7-8, Plate 5 bedding planes, 28–29*, 24, 32 inclined, 27, 38–9, Plate 1 bedload, 27*, 35, 36, 45 bees, 19, 12 beetles, 19, 4, 5 behavioural isolation, 21*, 25, 26 belemnite, 28-29, 17 Benioff, Hugo, 7-8, 35-6, 56, 81 Benioff zone see Wadati-Benioff 1,4-benzenedicarboxylic acid (terephthalic acid), 17-18, 82, benzene hexachloride (BHC), 17-18, 47 Bernard, Claude, 23, 38, Plate 11 beryllium, 13-14, 26-8, 31-2, 35-9 beta-blockers, 17-18, 63, 95; 23, 34 β-decay, 11-12*, 18, 19; 32, 4, 28-9, β-decay, 31*, 29, 30, 32-3, 36; 32, 15, 28-9 β⁺-decay, 31*, 30, 31, 32, 36; 32, 13, 14 β-farnesene, 17-18, 50, 51 β-glycosidic bonds, 22, 18 β-oxidation pathway, 22*, 45, 61, 62; 23, 26 β-particle, 11-12*, 18, 19, 23, 66 B-group vitamins, 22, 31-2 BHC (benzene hexachloride), 17-18, 47 bicarbonates anions, 13-14, 49; 15, 9, 10; 22, 14, 26; 25, 23; 26, 11, 18 formed during catabolism, 23, 21-2, 24 in oceans, 28-29, 59, 60, 61 Big Bang, 32*, 44, 45 Big European Bubble Chamber (BEBC), 32, 11 bilharzia, 19, 5 binary compounds, 13-14, 70 valency of, 13-14, 22 binding of substrate, 22, 26-7; 26, 10, 18 binding energy of a nucleus, 31*, 23, 25, 27, 29, 37 biochemistry, 22*, 3-4; 26, 9-12 chemical constitution of

organisms, 22, 14-24

biochemistry (continued) synthesis of chemical compounds, 22, 62-4 techniques, 22, 40-2 see also catabolism; enzymes; metabolism biogenic precipitation, 28-29, 63 biogeochemical cycles, 25*, 21, 22-32 acid rain and, 25, 30-1, 32 biological control of pests, 25*, 34-5, 53, 54, 55, 60-1 biology, 19*, 3 bioluminescence, 22*, 9 biomass, 25*, 10 increase in food chains and webs, 25, 12-14 biopolymers, 17-18*, 78; 22, 12, 17 biostratigraphic column, 28-29*, 24 biosynthesis, 22*, 3, 9, 24, 39, 64 see also anabolism biotic community see communities biotic factors, 25*, 3 birds, 26, 6-7, 14; 28-29, 12, 68, 70 adaptation by, 19, 14 body temperature, 23, 24 excretion, 23, 23 food chains and food webs and, 25, 11-12, 14-15 mortality factors and k-value analysis, 25, 39-43 mortality rates of holly leaf miners and, 25, 45-6, 47, 50, 51 oxygen supply, 23, 8-9, 10, 12 population fluctuations, 25, 34-9 as predators see peppered moth uric acid, excretion by, 22, 61; 23, 23 birth rates see natality Biston betularia see peppered moth bivalves, 28-29*, 9, 10, 68, 70 bladder, 23, 23 Blake, William, 1, 9-10 bleak (fish, Alburnus), 25, 17 blood, cells, 19, 6, 7; 23, 18-20, Plate 10 see also haemoglobin; red blood cells groups, 20, 52; 21, 11-12; 26, 16 pH of, 15, 29, 30 rhesus factor, 21, 11-12 system, 23, 8, 10, 20, 24; 26, 9, 11 exercise and, 23, 15-18, 20, 32, 33 heart and, 23, 12-14 oxygen transport in, 23, 11-12, 32 - 3, 37pressure, 23, 35 see also glucose levels bloodstream, 26, 9, 11 blue tits, 25, 46, 50 blue-green bacteria, 21, 29; 28-29*, 54, 55, 58, 61, 63, 65, 69 body cells see somatic cells body waves, 5-6, 90 Bohr, Niels, 13-14, 40; 30, 29; 31, 3 boiling see temperature bomb calorimetry techniques, 25, 13 bond dissociation energy (bond energies), 16*, 8, 9, 33 average, 16, 12, 13, 18 use of, 16, 9-13 limitations on, 16, 13-14 bond-breaking, 16, 8-10, 14, 15-16

bonding and structure of organic compounds, 17-18, 7-10, 37-8 bond-making, 16, 10, 14, 15-16 bone, 19, 5 Bonner, William, 17-18, 93 boron, 13-14, 26-8, 31-2, 35-9, 69 bosons see gauge bosons bottomness, 32*, 36, 37, 39 bottoms, naked, 32, 37 boulder clay, 7-8*, 56; 28-29, 74, 79, Plates 1 and 2 bound state of an electron, 11-12*, 40 box notation of electronic configuration, 11-12, 59-62 brachiopods, 28-29*, 9, 10, 67, 68, 70, Plate 23 bracken (Pteridium aquilinum), 25, 4, Plate 3a Brahe, Tycho: planetary tables, 2, 33, 35, 36 control systems in, 23, 31, 32-4 glucose needed for, 23, 24, 26 bramble (Rubus species), 25, 61 breathing, 23, 8-9, 10, 21-2 control mechanisms of, 23, 32-3, 34, 37 see also respiration Britain fossils, 7-8, 57 igneous rocks, 7-8, 66, 72 magnetic anomalies, 7-8, 41 mountains, 7-8, 22, 24-5 brittle deformation of rocks, 27*, 46, 47, 54 broad bean: chromosomes, 20, 11 bromine, 13-14, 19, 42-3, 65, 73, 74 in atmosphere, 28-29, 55 chemical reactions, 17-18, 38, 74 in compounds, 13-14, 54 carbon, 17-18, 9, 10, 15 as molecular covalent substance, 13-14, 53, 54, 56 in oceans, 28-29, 59, 60, 61 physical properties, 17-18, 11-12, 13 preparation of, 13-14, 54 bromochlorodifluoromethane (BCF), 17-18, 15, Plate 4 1-bromo-2-chloroethane, 17-18, 55 bronchi and bronchioles, 23, 9-10 Brookhaven accelerator, 32, 32 brown algae (Dinobryon divergens), 25, 33 bubble chamber, 30*, 10, 14; 32, 11, 20 bubonic plague, 25, 34 buffering by oceans, 25, 23, 24, 25, Bullard, Professor Sir Edward, 7-8, 27, 29, 37, 80, 81 bunsen burner, 13-14, 74 Burt, Sir Cyril, 1, 6 butanal, 17-18, 42 butan-1-amine, 17-18, 21 butane, 17-18, 14, 18-19, 22 butan-1-ol, 17-18, 20, 23, 34, 68, 73 butan-2-ol, 17-18, 34, 59, 62-3, 73 but-1-ene, 17-18, 38, 41-2 but-2-ene, 17-18, 38, 41-2, 44-5, 57 butterfly, meadow-brown, 26, 13-14 butyl acetate, 17-18, 68 butyne, 17-18, 38-9 butyric acid, 17-18, 64, 67

C

C see cytosine cactus, 19, 15, 16 caesium clock, 2, 8-9 isotopes, 28-29, 27 caesium chloride, 24, 20 Cainozoic Era, 28-29, 4, 8, 14-15 fossils in, 28-29, 12, 66, 68 in Stratigraphic Column, 28-29, 20-1, 23 see also Tertiary; Quaternary calcite, 27*, 5, 40, 41, Plate 8 in marine organisms, 28-29, 67 calcium, 13-14, 28, 29, 31-2, 36-9, 74 and life, 28-29, 62 in oceans, 28-29, 59-60, 61 in rocks, 27, 6, 9, 10, 11, 17, 20, 22-3, 41; 28-29, 53 calcium carbonate, 13-14, 53; 15, 4, 7, 10; 25, 24; 28-29, 58 deposition of, 27, 40, 41 neutralizing acid rain, 15, 32 calcium chloride, 28-29, 60 calcium fluoride, 13-14, 53 calcium hydroxide, 15, 5 solution of, 15, 9, 27 as conductor, 15, 7 caldera, 7-8*, 68, 69 'calendar, stone' (Stonehenge), 2, 4-5 calibration, 3, 25; 4*, 19 points, igneous rocks as, 28-29, 32 - 3, 35caloric, 9, 4 calories, 9, 12, 14 Calvin cycle, 22*, 64 Camarhynchus (tree finch), 26, 6 Cambrian Period fossils in, 28-29, 64, 67 in Stratigraphic Column, 28-29, 20-1, 23 camouflage, 19, 13 cancer, radioactivity as cause of, 31, 34, 35 capillaries, 22, 48; 23*, 12, 21 network, 26, 12 carbohydrates, 22*, 17, 24; 26, 15 catabolism of, 22, 42-59 digestion of, 23, 25 synthesis see photosynthesis see also glucose; monosaccharides; disaccharides; polysaccharides carbon, 11-12, 5, 10, 11, 12 chemical bonding, 13-14, 60, 61, 62, 63-4, 69-70 combustion of, 16, 2, 15 compounds characteristics of, 17-18, 7-18 number of, 17-18, 6 uses of, 17-18, 4-5, 9, 13-16, 40, 87 see also Lewis structures first ionization energy, 11-12, 64 isotopes, 11-12, 19, 20, 22; 22, 41; 28-29, 26 atomic mass of, 13-14, 16, 25 and life, 28-29, 57, 58, 60, 62, 65, 68 in meteorites, 28-29, 45, 46, 49, 80 in oceans, 28-29, 59, 60, 61 in rocks 27, 6, 11

carbon (continued) in sediments see Carboniferous Period sources of, in living organisms, 22, 8-9 carbon cycle, 25*, 21, 22, 23-5, 31 carbon dating, 11–12*, 21, 22, 23; 28–29, 26; 31, 28 carbon dioxide, 13-14, 20-1, 56; 22, 12; 26, 11, 12, 15, 18 in atmosphere, 28-29, 52, 55-6, 57, 58, 60, 61, 68, 72, 78 climate and, 28-29, 78, 79 carbon cycle and, 25, 22, 23-5, 31 chemical bonding, 13-14, 64 in greenhouse effect, 25, 25, 31; 28-29, 72, 78 Lewis structure, 17-18, 37 as molecular covalent substance, 13-14, 60, 61 in oceans, 25, 24; 28-29, 58, 61 production of, 15, 4 by oxidative catabolism, 22, 10,12 by yeast, 22, 57 in production ecology, 25, 13 reaction with water, 22, 26 reduction in photosynthesis, 22, 39, 62-3 removal of, 23, 21-2, 24 in rocks, 28-29, 60 solution as acid, 15, 9, 10, 30-1 transported in blood, 23, 11, 13, 18, 32-3, 35 carbon monoxide in atmosphere, 28-29, 55, 56 carbon tetrachloride, 13-14, 60, 61 carbonaceous chondrites, 28-29*, 45, carbonate ions, 13-14, 49; 25, 23 carbonic anhydrase, 22*, 26; 23*, 21; 26, 18 Carboniferous Period, 28-29, 4, 58, 59, 67-8 Coal Measures, 7-8, Plate 2; 28-29, 20-1, 24 fossils in, 28-29, 12, 67 ice age in, 28-29, 72 in Stratigraphic Column, 28-29, 20-1, 23 carbonyl group, 17-18*, 39, 86 carboxyl group, 17-18*, 39, 40 chemical reactions, 17-18, 67-8, 69, 70, 74, 82 in polymerization, 17-18, 81, 82 carboxylic acids, 17-18*, 39, 40, 70; 22, 15-16 chemical reactions, 17-18, 63, 64, 67-8, 69, 74 formation, 17-18, 72 unsaturation, 17-18, 39 see also fatty acids; tricarboxylic acid cycle cardiac output, 23*, 12, 20 and control mechanisms, 23, 32, 33, 34-5, 36, 37 measuring, 23, 15-18 see also heart Carey, Professor Warren S., 7-8, 80 Carlsberg Ridge, 7-8, 43, 44, 46 carnivores, 25, 62; 26, 12 biogeochemical cycles and, 25, 22, 26, 28 first, second and higher, 25, 11, 12, 14, 18, 22

food chains and food webs and, 25, 10, 11-14, 18 Carothers, Wallace, 17-18, 81, 96 Carroll, Lewis, 17-18, 62, 79 cartilage, 22, 17 carvone, 17-18, 58-9, 62, Plates 7-8 cassiterite, 27, 37 catabolism, 22*, 10, 38, 40, 61, 64; 23, 4, 9, 11; 26, 9 aerobic, 22, 47 of amino acids, 22, 61; 23, 23 anaerobic, 22, 57 of carbohydrates, 22, 42-59 of fatty acids, 22, 61 of fats, 22, 60-1; 23, 26, 27 of glucose, 22, 15, 27, 41-54, 58-9, of glycerol, 22, 60 of other fuels, 22, 60-1 products of, removing, 23, 11, 22-4 regulation of, 22, 58-9 catalysis by enzymes, 22, 25, 26-7, 33; 23, 36 in red cells, 23, 20, 24 see also enzymes catalysts, 16*, 25, 26-7 in reactions of carbon compounds, 17-18, 64, 67, 73, 75, 78, 88, 96 see also enzymes catastrophic event theory of origin of Solar System, 28-29*, 37, 41, 48 catastrophic theories of continental drift, 7-8, 17-18 catastrophism, 28-29*, 16, 19, 26, 50, 51 extinctions, 28-29, 68 catenation, 17-18*, 18, 19, 78 caterpillars and food chains and webs, **25**, 11–12, 13–15 cations, **13–14***, 46–7, 48, 49–50, 57, 59, 72, 73; 22, 14 in rocks, 27, 7, 9, 32, 33, 40, 41 Cavendish, Henry, gravitational constant and, 3, 37 cells, 19*, 5, 6-8, 9, 10, 11; 26, 3 animal, 19, 5-8; 22, 38-9; 26, 4, 15 blood, 19, 6-7; 23, 18-20, Plate 10; see also red cells; white cells cell cycle, 24, 14-15, 17 division, see eukaryote; inheritance; meiosis; mitosis; prokaryote growth and differentiation, 24, 15-16 membrane, 26, 4, 16 metabolism in, 22, 38-9; 26, 9 non-reproductive see somatic cells nucleus, 19, 8, 9, 10, 11; 26, 4, 16 DNA contents of, 24, 7-8 plant, 19, 5-8; 22, 63-64; 24, 46; 26, 4, 15 plant and animal compared, 22, 38-9 reproductive see gametes structure of (cytology), 20, 7 wall, 26, 4 see also DNA; eukaryotes; multicellular; organelles; prokaryotes; protein synthesis; single-celled cell-free system, 24*, 36, 37, 38 cellobiose, 22, 20 cellulase, 22*, 18, 19

cellulose, 19, 8; 22*, 17, 18, 19

Celsius, Anders, 9, 23 Celsius temperature scale, 9, 23-4, 29 cement, 5-6*, 8 Cenozoic see Cainozoic Era central core (of the Sun), 31, 39 central heating system, control of, 23, 28-9 central pathways, 22*, 60, 67 central rift see axial rift centrifuge/centrifugation, 22*, 40, 41, density-gradient, 24, 20, 21 centromere, 20*, 13, 14, 19, 29, 33, 46, 48, 49; 26, 16 cerebellum, 23, 32 cerebral cortex, 23*, 33 cerebrospinal fluid, 23*, 33 CERN, 32, 8, 10, 11, 28, 40, 41 Certhidia (warbler finch), 26, 6 chain polymerization, 17-18, 80 chain reactions, nuclear, 31, 38, 39, 40 chalk, 28-29, 16, 19, 20-1, 23-4 areas, 25, 23, 61, Plates 11-14 change of state and internal energy, 9, 27-30 characters see heritable character; inheritance characteristics see acquired characteristics charge, 9*, 4, 30, 31-4; 32, 13, 15, 19, 25 in atoms, 31, 11-12, 15, 18 of atoms, 11-12, 5, 7-9, 12-16, 18, 19,66-9 atomic spectra and, 11-12, 28, 36 conservation, 32, 19-20, 24 of electron, 9, 30-1, 32, 33; 30, 10, of gauge bosons, 32, 39-43 of leptons, 32, 13, 15, 31, 42-3 meaning of, 32, 19 moving, electrical energy and, 9, 32 - 3of quarks, 32, 26-8, 31, 36, 42-3 shells and subshells and, 11-12, 37, 38, 39 stationary, electrostatic force and, 9, 31-2 charm, 32*, 31-6 naked, 32, 34 Chase, Martha, 24, 7 checking calculations, 4, 25 chemical bonding, elementary theories of, 13-14, 57-72, 76; 17-18*, 8 electronegativity, 13-14, 65-8, 70-3; 17-18, 12 extended covalent substances, 13-14, 63-4 ionic bonding, 13-14, 59-60, 65, 70 metallic bonding, 13-14, 68-9, 70 metallic and non-metallic elements, boundary between, 13-14, 69-70 molecular covalent substances, 13-14, 53-5, 57, 60-1, 73 see also covalent bonding; noble gases; valency; weak bonds chemical composition, 13-14*, 14 of minerals, 27, 6-11, 19, 32, 50 chemical compounds, 13-14*, 5, 76 binary, 13-14, 22, 70 determining formulae of, 13-14, 11 - 14

chemical compounds (continued) numbers of, 17-18, 6 chemical constitution of organisms, 22, 7-8, 14-24 chemical element, 11-12*, 16 see also elements chemical energetics see chemical reactions chemical energy, 9*, 3, 4, 5 chemical equations, 11-12, 8; 13-14*, 19, 21, 76 chemical equilibrium, 15*, 3, 12, 13, 14-21 Le Chatelier's principle, 15*, 16, 17, 18, 22, 37; 16, 29-31 saturated solution, 15, 12-13, 20 chemical evolution, 17-18*, 91, 92 chemical formulae, 13-14*, 4, 25 chemical fuels, 16, 14, 15-18 chemical nature of life, 19, 8-9, 11 chemical precipitation, direct, 27, 41, 45 chemical reactions, 13-14*, 6-8, 9, 25 chemical fuels, 16, 14, 15-18 conditions for, 16, 28-30 energy and rockets, 16, 33-5 Haber-Bosch process, 16, 2, 30-2 rates of, 16, 2, 18-28, 29 chemical structure, 13-14*, 8 chemical symbol, 11-12*, 5, 11 chemical weathering, 27*, 31, 32 products of, 27, 33-4, 44 chemistry, 11-12*, 3 chemoreceptors, 23*, 33, 35, 37 Chernobyl accident, 31, 33 chert, 28-29*, 63, 64-5 chiasma (pl. chiasmata), 20*, 19; 26, 16 chilled margin, 27*, 22, 50 chimpanzee, 19, 5 china clay, 27, 33-4 chiral centre, 17-18*, 55, 60, 64 chirality, 17-18*, 52, 53-66 detection of, 17-18, 57-9 occurrence of, 17-18, 60-2 and origin of life, 17-18, 92-3 synthesis of chiral compounds, 17-18, 62-5 chironomids, 25, 17 chitin, 22, 17 chloride, excreted, 23, 26 see also acid chlorides chlorine, 13-14, 22, 25, 42-3, 73 in atmosphere, 28-29, 55, 56 chemical bonding, 13-14, 60, 61, 65, 66-7 in compounds, 13-14, 21, 27, 40, 41, 57, 63, 72 carbon, 17-18, 9, 10, 15 gas, 13-14, 50, 52 as molecular covalent substance, 13-14, 53, 56 in oceans, 28-29, 59, 60, 61 physical properties, 17-18, 11-12 in rocks, 27, 6, 41 1-chlorobutane, 17-18, 70 chloroethene (vinyl chloride), 17-18, chloroform, 13-14, 56 chloromethane, 17-18, 14 chlorophyll, 22, 38, 63 chloroplasts, 19, 8; 22*, 38, 63-4, Plates 6 and 7; 24, 38; 25, 7, 8; 26, 15

chondrites, 28-29*, 44, 45, 46, 47, 49, chondritic Earth model, 28-29*, 47, 49, 57 chondroitin sulphate, 22, 17 chondrules, 28-29*, 44, 45, 51 Chordata, 21, 31, 32 chromatids, 20*, 13, 14, 19-20, 22, 24, 27-8, 29, 46, 48, 49; 24, 4, 7; 26, 5, 15, 16 inheritance of characters and, 20, 24, 27-9 see also meiosis; mitosis chromatin, 20*, 10; 26, 4 packing, 20, 10, 18, 50 see also chromosomes chromatography, gas, 17-18, 19, 49 chromium, 11-12, 61-2 in rocks, 27, 23, 37; 28-29, 46 chromodynamics, quantum, 32, 29, 33.41 - 2chromosomes, 19*, 9, 11; 20*, 8, 9; 22, 6; 24, 4, 8, 14, 42; 26, 3, 5, 6, 13, 15, 16 banding patterns, 20, 18, 50, 51 damaged by ionizing radiation, 24, 40; 31, 34, 35 DNA and, 20, 8-10; 24, 7 gametes production and, 20, 11-17 genetic abnormalities, 20, 20-1 human, 20, 9, 18, 20-1 independent assortment and, 20, 33-40 numbers of (haploid and diploid), 20, 11, 12, 17, 22, 24, 25-6, 48 see also chromatids; chromatin; DNA; genes; genetic; homologous pairs; inheritance; meiosis, mitosis Chthamalus stellatus (barnacle), 25, 57, 58 cilia, 23, 11 circular, accelerator see synchrotron motion, 1, 23, 24-6, 40, 41 wave, 10, 25, 30, 33 circulatory systems, 23, 10-21, 34 see also blood system circumference of a circle, 2, 17-18, 30 cis isomer, 17-18*, 44, 48, 49, 50, 51, citric acid, 22*, 45, 50, 54, 58 citric acid cycle see tricarboxylic acid cycle class (biology), 21*, 29, 32, 33; 26, 3, 15 class of (organic) compounds, 17-18*, classical mechanics, 3*, 40 see also Newtonian mechanics classification and evolution, 21, 27-34 evolutionary trees, 21, 28, 33 taxonomic hierarchy, 21, 27, 29-32 clay, 28-29, 19, 20-1, 74 boulder, 7-8, 56; 28-29, 74, 79 deposits, interglacial, 28-29, 74 varves, **28–29**, 7–8, 13 **clay minerals**, **27***, 15, 33, 49 Clean Air Act (1958), 19, 29 cleavage in minerals, 27*, 6, 7, Plates

7.8

cleavage in rocks, 27*, 49, 54

changes, 28-29, 22, 68, 70-9 and speciation, 21, 22-4 climatic belts, 7-8, Plate 4; 28-29, 70-2 recent, 28-29, 72-4 past, 7-8, 18-19, 20-1, 26, 56-7 evidence of, 7-8, Plates 1, 2, 3, 5 see also ice ages climax community, 25*, 60, 62 cling film, 17-18, 85 Clostridium tetani (tetanus microbe), 22, 57 clotting mechanism, 23, 18, 20 coal, deposition of, 7-8, 21, 56-7 Coal Measures see Carboniferous Period coal tits, 25, 46, 50 coastal areas see shores cobalt in rocks, 28-29, 47 cockles, 28-29, Plates 24a, 24b coding DNA, 24*, 45 see also genetic code codons, 24*, 27, 28, 29, 31; 26, 9, 17, 18 genetic code and, 24, 35-7, 38 mutation and, 24, 41 stop, 24, 29, 34, 37, 38, 39; 26, 17 coenzymes, 22*, 30, 31-2, 46, 51, 55, 64 coenzyme A, 22, 31, 46 colliding-beam experiments, 32*, 9, 10, 32, 34, 41 collisions, analysis of, 9, 20-2 collisions of particles α-particles, 11-12, 13, 14; 32, 24-5 electrons, 11-12, 7-8 frequency, 16, 20 at high energies, 32, 5, 6-7, 9, 10-11, 12 collision model of a chemical reaction, **16***, 20, 21–2, 27, 28, 29 collision, plate, **7–8**, 72, 74 colonization, 26, 8, 17 colorimeter, 23*, 17 colour forms of moths, experiments with, **19**, 16–19, 20, 27–9, 30–1 of light, 10, 35-7 of minerals, 27, 7, 9, 11, 16 'colour' of quarks and gluons, 32, 29, combustion reaction, 16*, 2, 3 chemical fuels, 16, 15-18 see also fossil fuels common logarithm, 15, 27 communities, biotic, 25*, 3, 4-5, 6, 57-62 rabbits and vegetation, 25, 60-2 compact disc, 10, 41 rotation of, 1, 19 comparison of adaptive forms, 19, 16 of fecundity and viability, 19, 22-5 compass, 5-6, 40, 41, 44, 45-6, 47-8 competition, 19*, 32; 26, 8, 14, 17 complementary bases, 24*, 11, 12, 25 components of momentum, 30*, 25, 26-9, 31, 32 components of position, 30*, 25, 26-9, 31, 32 components of velocity, 30*, 25, 26-9 composite cones, 27*, 20 compounds see chemical compounds; unsaturated compounds

6-8, 9 compression, structures formed 20, 21, 24, 29, 31, 32-4, 35, 36, formation of, 13-14, 9, 46, 48 under, 27, 46-7, 48-9 consumers/consumption, 25*, 11, metal, 13-14, 5, 6-9, 17-21 compression pulse, 5-6*, 26, 29-30 in rocks, 27, 6 compressional wave motion, 5-6*, 25, 12-14, 18; 26, 12 tolerance of grass to, 21, 9, 10 contact metamorphism, 27*, 50, 54; 26, 27, 90 valency of, investigating, 13-14, 23 see also P-waves 28-29*, 32, 33 wire, stretching of, 4, 9-12 continents, origin of, 27, 26-7, 28-9 Compton, Arthur, 30, 9 continental crust, 5-6*, 78, 79 continental drift, 1, 8; 5-6*, 86 copper chloride, 13-14, 9, 42-3 Compton effect, 10*, 3, 48, 49, 50; as ionic substance, 13-14, 45, 46-8, 30*, 8, 9, 13, 14 51, 56 and ice ages, 28-29, 77, 79 computers and continental fit, 7-8, valency, 13-14, 21, 24 time when occurred, 32, 45 27, 58 continental drift theories, 7-8*, 17 copper oxide, 13-14, 9, 19-20, 26, 28, concentration catastrophic, 7-8, 17-18 63 molecular interpretation of effects Holmes', 7–8, 25–6 plate tectonics and, 7–8, 27, 28, empirical formula, 13-14, 10 of, 16, 20-1 molecular formula, 13-14, 18 of reactants in chemical reactions, oxidation of, 17-18, 70-1 56-9 16, 19, 20, 21, 27, 28, 29 reactions, 13-14, 21 stabilists', 7-8, 23-4 concentration gradient, 22*, 9, 56; valency and, 13-14, 23-4 Wegener's 23*, 6, 10, 22; 26, 18 coral, 28-29*, 9, 10, 67, Plates 26, 30 evidence for, 7-8, 18-23, 26 concentration of a solution, 15*, 11, mechanisms for, 7-8, 23 12, 19, 20 of Earth, 5-6*, 12, 60, 68-76, 81; reactions to, 7-8, 23-6 condensation polymers/ 28-29, 41-2, 49, 50 continental fit polymerization, 17-18*, 78, composition of, 5-6, 69, 72, 75-6 81-3, 89; 19, 10; 22, 17, 24; computers and, 7-8, 27, 58 continental drift theories and, 7-8, inner, 5-6, 74, 75, 81; 28-29, 42, 24, 24 18-19, 20, 24, 26, 58 49 condensation reactions, 17-18*, 74, 97 as source of Earth's magnetic plate tectonics and, 7-8, 27-9 conditions for chemical reactions, 16, field, 5-6, 69-72 continental rise, 7-8*, 10 28-30 continental shelf, 7-8*, 10 structure of, 5-6, 72-5 conductivity, electrical, 13-14, 43-8, continental slope, 7-8*, 10 of planets, 28-29, 45, 49, 50, 51 69,72 of Sun, 31, 39 continent/continent collision, 7-8, 71, conductor, electrical, 5-6, 69, 70-1, coronary blood vessels, 23, 13, 14 72; 28-29, 80-1 76 correlation, 28-29*, 8 continent/continent destructive plate configuration, 17-18*, 60 corroboration of scientific theory, 1, margin, 7-8, 71, 72 confined particles and quantum continuous refraction, 5-6*, 36 7, 43 mechanics, 31, 4-10 cortex in one dimension, 31, 5-8, 10 continuous spectrum, 11-12*, 25 adrenal, 23, 36 continuum, 11-12*, 33 in three dimensions, 31, 8-10, cerebral, 23, 33 continuum level, 11-12*, 33 11-14, 21-2 contractile proteins, 22, 20 cosine (cos), 2*, 32 conformations, 17-18*, 27 cosmic rays, 31, 35; 32*, 5, 13, 14, 42, control see control genes; control conglomerates, 28-29, 53, 60 43 conical surface, 1, 13 mechanisms; regulation control genes, 24*, 16 cotton, 17-18, 86 Connell, J.H., 25, 57, 59 cottony cushion scale insect (Icerya control group, 4*, 16 conservation purchasi), 25, 54, Plate 10 control mechanisms, 23, 28-38 of baryon number, 32, 20-1 coulomb, 9*, 31, 34 of blood glucose level, 23, 31-2 of bottomness, 32, 36 Coulomb, Charles de, 9, 31 of charge, 32, 19-20 of breathing, 23, 32-3, 34, 37 Coulomb's law, 9*, 31, 32, 35; 31, 11, of heart beat of charm, 32, 34 20; 32, 16 hormonal, 23, 35-7 of strangeness, 32, 22-3 and atomic structure, 11-12, 15, nervous 23, 33-5, 37 of topness, 32, 36 28, 38 of temperature, 23, 23-4, 30-31 conservation of elements, 13-14*, 8, 9 controlled nuclear chain reaction, 31, covalent bonding, 13-14*, 61, 62-3, conservation of energy, 9, 5-9; 30, 9, 65, 70; 16, 7, 9, 14; 17-18, 8 40 16 in DNA, 24, 11, 17, 24, 31 law of, 9*, 6-7, 9, 13, 20-2, 35-6; convection currents covalent molecules, forces between continental drift theories and, 7-8, 11-12, 39; 16, 11, 24; 22, 66; see intermolecular forces 25 - 625, 7, 15, 18; 31, 29, 32 covalent substances, 13-14, 68, 70, 76 in mantle, 27, 18 and photoelectric effect, 10, 46 extended, 13-14, 63-4 plate margins and, 7-8, 76-8, 79 see also production ecology Cox, K., 7-8, 81 plate tectonics and, 7-8, 35, 37, conservation of mass, 13-14*, 15 cratons, 7-8*, 12, 15, 16, 28, 29 38-9, 43, 44 conservation of momentum, law of, creep in rocks, 27*, 47 convergence, 19*, 14, 15 3*, 16; 9, 20-2, 36; 16, 34; 30, crest of a wave, 10*, 11 9, 16, 24; 32, 7, 9 conversion of energy see energy Cretaceous Period, 26, 14; 28-29, 17 conversion conservative plate margin, 7-8*, 59, convex lens, 10*, 30, 31, 32, 34 fossils in, 28-29, 12, 68 60-2, 73-5, 79 in Stratigraphic Column, 28-29, cooling Earth theory, 7-8, 17, 18 conserved quantity, 3*, 16 20 - 1, 23conspicuousness see peppered moth; Cooper, Leon, 30, 34 Crick, Francis, 24, 3, 10, 12, 37 co-ordination, 23, 4 stick insect crinoids, 28-29*, 9, 10, 68, 70, Plate 30 Copernicus, Nicolas: theory of constant of proportionality, 2*, 40, 41 critical angle of incidence, 5-6*, 35, planetary orbits, 2, 30-3; constellations, 1*, 18, 22 39, 72 constructive plate margin, 7-8*, 59, 28-29, 37 critical angle of refraction, 5-6, 72-3 Copernican model, 1, 32 60-2, 63-9, 77, 78 copolymers, 17–18*, 78 copper, 11–12, 5, 10, 17, 63, 81; 13–14, cross-bedding in rocks, 27, 38-9, 45, and metamorphism, 27, 51 Plates 12, 13 and origin of basalts, 27, 20-1, 25, 30, 76; 28-29, 21, 46, 52 cross-bedding in sand-dunes, 7-8, 57 26, 29 cross-fertilization (crossing), 20*, 3, 4, in alloy, 13-14, 69, 74 constructive superposition/

compounds, reactions of, 13-14,

constructive interference, 10*,

cross-fertilization (continued) see also inheritance; linkage crossbills, 25, 36 crossed polarizers, 17-18, 58-9 crosses, genetic, 20, 4; 26, 6, 16 see also first filial generation; parental generation; second filial generation crossing over, 20*, 13, 14, 19-20, 24, 27, 35, 42, 43, 44, 50; 26, 5, 16 crust, Earth's/crustal, 5-6*, 11, 22, 60, 76–9, 80, 81; **7–8**, 5–16, 33–4; 28-29, 45-6, 50 blocks see plate tectonics continental drift theories and, 7-8, 18-19, 26 continents formed, 7-8, 5-7, 70 Earth patterns, 7-8, 11-12, 13 lithosphere, 7-8, 33-4, 35, 38 plates, names of, 7-8, 55, 61 structure, 5-6, 77-9 see also geology; plate margins; rocks and under continental crust; ocean crust crustaceans, 28-29, 67, 68, 70 crystalline texture, 5-6*, 8, Plate 15 crystallites, 17-18*, 84, 85, 91 crystallization, 27, 41 fractional, 27, 22-4, 29 from melt, 27, 5, 15, 16, 20-3, 25, 28, 29 of silicate minerals, 27, 9-11 temperature, 27, 10-11, 16 crystallography, X-ray, 17-18, 84 C-terminal amino acid residue, 22*, 21; 24*, 28, 29 culmination point, 1*, 15, 16 cumulates, 27*, 23, 24 cumulative area, 7-8, 8 cumulative frequency curve, 7-8, 9 Curie temperature, 5-6*, 57, 83 current, electric see electric current current loops, 5-6*, 70 currents, water, transport and deposition of sediments by, 27, 36 curved surfaces, 1, 13 Cuvier, Georges, 28-29, 11, 15-16 Cyanea (jellyfish): oxygen supply, 23, 7 - 8cyanide compounds, 22, 56 cyclical regeneration, 25*, 60, 62 cylindrical surfaces, 1, 13 cysteine (Cys), 22, 21, 22, 45, 64; 24, 36 cytochromes, 22*, 45, 52, 55, 56 cytology, 20*, 7 cytoplasm, 24*, 21-2, 23, 29 cytosine (C), 17-18, 89; 24*, 10, 11 - 12cytosol, 19*, 8; 22, 3, 6, 9, 38, 40, 44, 46; 24, 21, 23

D

Dacron, 17–18, 82
Dalton, John, 11–12, 3
dark stage of photosynthesis, 22*, 63, 64

Darwin, Charles, 17–18, 91; 19*, 11, 12, 15, 29, 32, 34, 36, 37; 20, 31; 26, 6; 28–29, 11, 64

Origin of Species, 19, 32, 36

theory of evolution by natural selection, 19*, 11 see also evolution data, experimental, 1, 20 handling, 4, 9-23 quoting experimental results, 4, 21 standard deviation, 4, 25-7 tabulating, 4, 8, 9 see also graphs; practical work; uncertainties dating methods absolute, 28-29, 24, 35 radiometric, 28-29, 24, 26-9, 32-5, 36-7 minerals and, 28-29, 30-1 relative, 28-29, 12, 32-3, 35 see also age of Earth; carbon dating; geological; radioactivity; rocks; time daughter double helices, 24*, 18, 19 daughter isotope, 28-29*, 27, 28-9, 30, 31, 36 Davisson, Clinton, 30, 11, 12 Davy, Sir Humphry, 13-14, 74 day and night, 1, 15-16, 22, 24 cause of, 1, 26-8, 41 day, solar, 1, 16, 22 D configuration, 17-18, 60-1, 93; 22, DDT, 17-18, 5, 47; 25, 54 deamination, 22*, 61; 23, 23 caused by ionizing radiation, 31, rates see mortality de Broglie, Prince Louis, 30, 10, 11, de Broglie's formula and wave model, 30*, 10, 11-12, 13, 14, 27, 33-4; 31, 5, 6; 32, 6, 24 Debye, Peter, 10, 48 decan-1-amine, 17-18, 21 decane, 17-18, 19, 40 decanoic acid, 17-18, 40 decay chain, nuclear, 31, 32, 33 channel, nuclear, 31, 32, 37, 38 radioactive see radioactive decay types of, 32, 18-19 deciphering the genetic code, 24, 36-8 declination, magnetic, 5-6, 49, 52, 82 decomposers, 25*, 11, 12-14, 16-17, 18; 26, 18 biogeochemical cycles and, 25, 22, 26, 28, 31 deduction, 1, 7, 8 defence mechanisms, 19, 13 degeneracy, 11-12*, 55-8; 31*, 9 degenerate code, 24*, 37 dehydration, 23, 26 dehydrogenases, 22, 31, 45, 57, 58-9 dehydrogenation, 22*, 31, 57 deletion (of a base), 24, 41; 26, 8, 17 Deltamethrin, 17-18, 47 deluge see flood denaturation (of an enzyme), 22, 28-30; 26, 18 denitrification, 25*, 27, 28, 29 thermal, 22, 28, 29 density, 3*, 37, 40 of air and reflection of sound waves, 10, 4-6 of atomic nucleus, 31, 17

of crustal material, 7-8, 5, 9 see also gravity anomalies of diamond and graphite, 5-6, 66 of Earth, 3, 36-8 interior, 5-6, 10, 11, 63-5, 75, 81 of Moon, 3, 38-9 of planets, 28-29, 39, 41, 47-8 of rocks, 5-6, 10-11, 12, 60, 63-5, 81 wave speeds and, 5-6, 29, 30-1, 32-3, 63-5 of silicate minerals, 27, 11-15, 16, investigation, 27, 12-14 density-gradient centrifugation, 24*, 20, 21 density-dependent mortality rates, 25*, 36 density-dependent natality rates, 25, 36, 41, 42 density-independent mortality rates, 25*, 36-7, 42 denudation, 27*, 34 deoxyribonucleic acid see DNA deoxyribonucleotides, 24*, 10 see also nucleotides deoxyribose, 17-18, 89; 22, 15; 24*, 10, 11, 12 dependent variable, 4*, 11, 24 deposition of sediments, 27, 35-6, 38-41, 45, 53 deposits see sediments Descartes, René: invention of graph, 2, 37 deserts, 25, 9, 18 seed-eating rodents in, 25, 58-9 designing experiments, 4, 4-6 destructive plate margin, 7-8*, 59, 60-2, 69-73, 77-8, 79; 28-29, 33, 50 and metamorphism, 27, 51, 52-3 and origin of andesites, 27, 24-9, destructive superposition/destructive interference, 10*, 21, 24, 29, 30, 31, 32–3, 53 DESY, 32, 10, 35 detectors (particle), 32, 10-12, 33, 35, 37, 41 detrital grains, 28-29*, 53, 59 detritivores, 25*, 11, 12-14, 16-17, 18; biogeochemical cycles and, 25, 26, detritus, 25*, 11, 16-17, 18 biogeochemical cycles and, 25, 26, Devonian Period, 28-29, 57-8 fossils in, 28-29, 12, 67 in Stratigraphic Column, 28-29, 20-1, 23 dextrins, 22, 33; 26, 18 D-glucose see glucose diabetes, 23*, 26, 27; 24, 46 diamond, 13-14, 63-4, 69 density of, 5-6, 66 structure of, 17-18, 25 diaphragm, 23, 10 diapirs, 27*, 25, 28 diatoms, 25, 16-17 diatomic ions, 13-14, 73 diatomic molecules, 13-14, 19 bond energies for, 16, 8-12, 14 dibromoalkane, 17-18, 74

dichlorides, 13-14, 66 dichlorofluoromethane, 17-18, 14-15 Dieldrin, 17-18, 47 Dietz, Robert S., 7-8, 40, 81 **differentiation, 24***, 15, 16, 17 **diffraction, 10***, 6, 7–10, 25–38, 53, 54; 30, 6-7, 13 Fraunhofer, 10, 30-1 Huygen's construction, 10, 25-30 of matter, 30, 11, 12, 13, 14-17, 26-7, 32 macroscopic, 30, 3, 33-4, 35 observing, 10, 7-10 pattern, 10, 35; 30, 14-15 and colour, 10, 35-6 at infinity, 10, 30-1 by single-slit, 10, 6, 7, 8-9, 26-8; 30, 14-17, 26-8, 33-4 see also double-slit diffraction diffraction equation, 10*, 33, 34 diffraction grating, 10*, 9, 10, 33-6; 30, 6, 7, 11 diffraction order, 10*, 34, 36 diffusion of oxygen, 23*, 6 see also oxygen supply digestion, 22, 38, 48; 26, 9-12 of carbohydrates, 23, 25 dihydroxyacetone phosphate, 22, 45, dilatation (rarefaction), 5-6, 26, 90 dilute solutions, 15, 20 dimensions, 2*, 12, 13 of energy, 9, 13 dimensional analysis, 2, 13, 41 dinosaurs, 26, 14; 28-29*, 9, 17, 68, 81, Plate 31 time when roamed, 28-29, 12; 32, 45 diorite, 27, 26 dipeptides, 24, 29, 33 diploid number of chromosomes, 20*, 11, 12, 17, 22, 24, 25-6, 45; **26**, 15 see also mitosis; somatic cells Dipodomys species (seed-eating rodent), 25, 58 dipolar magnetic field, 5-6, 47, 51, 70, 72 dipole electric, 17-18, 11 magnetic, 5-6, 47, 52, 55, 56, 58 dipole-dipole forces, 17-18*, 11, 12, 13, 23, 87 dipole wobble, 5-6*, 55, 70, 83 dip poles, magnetic, 5-6, 52, 55 Dirac, Paul, 32, 14 disaccharides, 22, 17 discontinuous variation, 20*, 4 diseases heritable, 19, 31 human, 21, 12, 14, 16-19; 23, 26, 29; 24, 40, 46; 25, 34 parasites and, 19, 5, 6 population size and, 19, 22, 23; 25, 34 viruses and, 19, 3, 9 displacive forces, 7-8, 23 dissociation, constant, of acids, 15, 23 photochemical, of water, 28-29, 55, 57, 60 see also bond dissociation energy distribution of silicate minerals, 27, 15-16

disulphide bridges, 22*, 22; 24, 46 di-tertiary-butyl peroxide, 17-18, 96 diversity of life, 19, 4-5; 26, 3-4, 6, 14 divisions I and II of meiosis, 20*, 13, 14-16, 27-8, 29, 34, 36-7 DNA (deoxyribonucleic acid), 17-18*, 89; 19, 8, 9, 10, 11; 20, 2, 23; 22, 5-7, 23, 38, 64; 24*, 4, 5-13, 17-21, 50; 26, 8, 16, 17, 18 chromosomes and, 20, 8-10 contemporary views, 24, 44-9 content in nuclei, 24, 7-8 damaged by ionizing radiation, 24, 41, 43; 31, 34, 35 evidence from viruses, 24, 6-7 as genetic substance of organisms, 24, 7-8 investigating structure of, 24, 9-12; makes RNA, 24, 23, 24-6 molecular structure of, 17-18, 90; 24, 9-13 mRNA, protein and, 24, 22, 24, 27, 44-5 mutations and, 24, 40, 41, 50 non-coding, 24, 45, 47 non-ionizing radiation and changes in DNA, 24, 41, 43 replication, 24, 17-21, 50 evidence for semi-conservative replication, 24, 19-20 theoretical scheme for, 24, 17-19 see also chromatin; genes; inheritance; transcription DNA repair mechanisms, 24*, 41, 43 Dobson units, 17-18, 16, Plate 5 dogfish, adaptation by, 19, 13, 14 dogwhelk (Nucella lapillus), 25, 58 dominant allele and character, 20*, 27, 30, 33, 41; 21, 4, 6-8, 10, 17; 26, 5, 6, 16 molecular explanation of, 24, 42-3 double bond, 13-14*, 61, 62; 17-18, see also unsaturated compounds double circulation, 23*, 13, 20 double helix, 24*, 9, 10, 11, 12, 17-19, 21, 24, 25, 50 daughter, 24, 18, 19 double-slit diffraction, 10*, 6, 7, 9, 28-30, 31-3 and Huygen's construction, 10, 25, 28-30 down (d) quarks, 32, 26-30, 31, 35, 36, 37, 43 Down's syndrome, **20**, 20–1 **drift chamber**, **32***, 10, 11, 41 drilling, deep-sea, **7–8**, 47–50, 63 Drosophila (fruit-fly), 20, Plate 12; 21, 13, 14, 15, 21, 26, 30 chromosomes, 20, 50, 51 eye colour, 24, 42, 43 linkage in, 20, 40-4 drugs see pharmaceuticals dry-cleaning solvents, 13-14, 55, 57; 17-18, 23 duality, wave-particle, of electromagnetic radiation see wave-particle duality ductile material, 7-8, 32-3, 34, 76 duodenum, 26, 10, 11, 18 Du Toit, Alexander, 7-8, 25, 26, 35,

dykes, 7–8*, 63, 64, 65, 68, 78; 28–29, 32, 33 dynamic balance, state of, 15, 13–15 dynamo, self-exciting, 5–6, 71, 87

E

e see electron Earth, 1, 4 age of, 28-29, 4, 35-7 fossils used to determine, 28-29, 8, 11, 13, 24, 34 varves used to determine, 28-29, 8, 13 see also dating; geological; time as centre of planetary orbits, 2, 33 chondritic model, 28-29, 47, 49, 57 circular motion, 1, 24-6 climate and vegetation belts, 28-29, 71 see also climate changes; ice ages core of, 5-6, 12, 60, 68-76, 81; 28-29, 41-2, 49, 50 composition of, 5-6, 69, 72, 75-6 inner, 5-6, 74, 75, 81; 28-29, 42, as source of Earth's magnetic field, 5-6, 69-72 structure of, 5-6, 72-5 crust of, 5-6, 11, 22, 60, 76-9, 80, 81; 7-8, 5-16, 33-4; 28-29, 45-6, 50 distance to Moon, 2, 22-6, 29 distance to Sun, 2, 26-8, 29 internal temperature, 27, 4, 18-19, 29; 28-29, 26, 57 interior density, 5-6, 10, 11, 63-5, 75, 81 modelling, 5-6, 6, 11-12, 60-79 seismic model, simple, 5-6, see also core; crust; mantle; temperature magnetism, 5-6, 40-59 mantle, 5-6, 12, 60, 77; 28-29, 42, 49, 50, 51 composition of see peridotite properties of, 5-6, 68, 81 structure of, 5-6, 66-8; 7-8, 33-4 mass and density of, 3, 36-8; 5-6, 10, 11, 63-5, 75, 81 Moon and: forces of attraction between, 3, 22 movements see tectonic processes orbit and rotation, 1, 28-29, 30, 31, 32-3, 35-7; 2, 30, 32, 35, 36, 38, 40 geometric variations in, 28-29, origin of Solar System and, 28-29, 38-9, 41 periodicity, 1, 18-22 photograph of, 1, 5; 5-6, Plate 1 planets as observed from, 1, 18, 22, 32 - 3, 45radius of, 2, 15-20, 21-2, 29, 44-6; 5-6, 6, 7 'reflectiveness' of (albedo), 28-29, 78

size and shape of, 1, 11-15, 43;

5-6, 7

Earth (continued) spin, 1, 25-8 stars and, 1, 11, 13, 18, 40-1 Sun and Moon as observed from, 1, 12, 17-18, 34-8, 41-3, 44, 45 temperature, 5-6, 7-8, 56, 57, 67 see also density; earthquakes; life; magnetism; rocks; seismic earthquakes, 5-6, 4-5, 12, 13-38 damage due to, 5-6, 4, 5, 22 detecting and recording, 5-6, 17-21, 22, 24, 26, 37-8, 89-90, Plate 21b destructive power, 5-6, 20 distribution of, 5-6, 16, 22 energy from, 9, 12 epicentre of, 5-6, 14, 16, 61-2, 90 focus of, 5-6, 14, 22, 38, 89 intensity of, 5-6, 14, 20, 37 magnitude of, 5-6, 19, 20, 21, 22, 89 prediction, 5-6, 91-3 reasons for, 5-6, 14-15 see also seismic; seismic waves Earth sciences, 5–6*, 4, 5–23 origins of, 5-6, 4-5 scope and methods, 5-6, 5-7 see also Earth; earthquakes; magnetism; seismic East Indies gravity anomalies, 7-8, 34-5 volcanic and seismic activity, 7-8, East Pacific Ridge, 7-8, 11, 37, 73, 81 echinoid, 28-29*, 9, 10 eclipse, 1*, 35 lunar, 1, 35, 37-8, 42, 43; 2, 20-1, 45-6 solar, 1, 37-8; 2, 28-9 eclipsing the Moon (experiment), 2, 22-6, 45-6 ecliptic plane, 28-29*, 70 ecology, 22, 38; 25*, 5, 6, 63; 26, 12-14 of past, 28-29, 11, 13 see also biogeochemical cycles; communities; ecosystems; population; production ecology ecosystems, 25*, 5, 6; 26, 13-14 production ecology and, 25, 6-20 aquatic, energy flow in, 25, 16-17 food chains and food webs, 25, 11-15, 18 primary producers, 25, 7-11, 18, 24-5 see also aquatic ecosystems Ediacaran fauna, 28-29*, 65 effectors, 23*, 28, 31, 33, 37; 26, 11, effusive rocks, 5-6*, 8, 77 effusive volcanic activity, 7-8, 15, 16 eggs, 20*, 3, 4, 6, 8, 17 production of, 20, 20 sizes of, 20, 9 see also gametes; meiosis Einstein, Albert, 9, 35; 10, 3, 42, 44-5; 30, 7 on common sense, 30, 5 Nobel Prize, 30, 7 particle theory of light, 10, 44-8, on science and thought, 1, 4, 8

on speed of light, 2, 8 theory of relativity 3, 15; 10, 45, 48 see also relativity on uncertainty principle, 30, 29 Einstein's equation, 31*, 4, 24, 26, 27, 29, 30, 32, 42; 32, 6, 7 Einstein's photoelectric equation, 10*, 46, 47-8 elastic and inelastic collisions, 9, 20-2; 10, 48 elasticity, 5-6*, 25, 26, 30-3 elastic material, 5-6, 29-30; 7-8, 32 - 3elastic modulus, 5-6*, 29, 30, 31, 32, 60, 63-4, 67 elder (Sambucus nigra), 25, 61 electric charge see charge electric current, 5-6*, 69, 70-2, 87; 9*, 8, 30, 34, 35; 11-12, 66, 69; 13-14, 69 electric dipole, 17-18*, 11 electric field, 10, 39; 11-12, 5-6 electrical conductivity, 13-14, 43-8, 69-70, 72 electrical conductor, 5-6*, 69, 70-1 electrical energy, 9*, 4, 5, 6-7, 23, 30-5 electricity produced from nuclear power, 31, 39-41 electrodes, 13-14*, 46, 47-50 oxygen, 22, 42 electrodynamics, quantum, 10, 52; 30, 13, 17 electrolysis, 9, 8; 13-14*, 45, 46, 47-8, 50, 54, 74 electrolyte, 13-14*, 46, 50, 51; 15, 7 strong, 15, 18, 19, 20 weak, 15, 19 electromagnetic interaction, 32, 4 gauge bosons, 32, 38, 39, 40 hadrons, 32, 18-19 leptons, 32, 16, 35 quarks, 32, 28, 29, 31 electromagnetic radiation, 10*, 39, 40, 41, 42, 51; 11-12, 20, 28; 30, 5-9, 14, 17; 31, 3, 8 models of, 30, 6-9, 13, 14 particle, 30, 7-9, 14 wave, 30, 6-7, 14 electromagnetic spectrum, 10*, 40, 41, 45; 11-12, 30; 30, 6 electromagnetic waves, 10*, 3, 39, 40, 41, 51 light modelled as, 17-18, 57 electromagnetism, 5-6, 69-71 Maxwell's theory of, 10, 39 see also electromagnetic waves electron, 5-6, 69; 9, 4; 11-12, 66-9; 32*, 13, 14-15, 16, 43 atoms and, 11-12, 66-9; 30, 29-31 charge of, 9, 30-1, 32, 33; 30, 10, 14 and Compton effect, 10, 48, 49, 50 diffraction of see diffraction of matter discovered, 30, 10 energy levels, 11-12, 29, 41-2, 43; 30, 4; 31, 11-17 flow of, 9, 30 gain in reduction, 17-18, 71 loss in oxidation, 17-18, 71 in photosynthesis, 22, 63-64 interactions, 30, 10; 32, 15-16 irradiation of leucine, 17-18, 93 mass of, 30, 10, 14; 32, 13, 15, 43

in metallic crystals, 30, 11 paired, 11-12, 55; 13-14, 59, 61 electron-pair bonds, 13-14, 61, 62 and photoelectric effect, 10, 42, 43-8, 50, 53; 30, 7-8 scattering of, 32, 24-5 unbound, 11-12, 40 unpaired, 11-12, 55, 60 see also matter electron antineutrino see antineutrinos electron energy levels, 11-12*, 29, 41-2, 43; 30, 4 shells and subshells, 11-12, 37-46 electron energy-level diagram, 11-12*, 29, 30, 31, 35, 36, 38, 43, 70 and shells and subshells, 11-12, 38, 40, 42, 44, 47, 49, 51, 52 electron micrographs, 19, 6; 22, Plates 4, 5, 6; 23, Plate 10; 24, 30 electron microscopy, scanning, 17-18, 86; 19, 6 electron neutrino see neutrinos electron pair bonds, 13-14, 61, 62 electron sharing, 13-14, 59, 61 electron shells and subshells, 11-12*. 37-41, 42, 43-6; 13-14, 34-5 degeneracy, 11-12, 55-8 electronic configuration, 11-12, 58-63 electron spin, 11-12*, 52-3, 54, 55-7, 59-60 magnetic spin quantum number, 11-12, 53-5, 58 uniform and non-uniform magnetic fields, 11-12, 53, 54 electron subshells see electron shells electronegativity, 13-14*, 65, 66-8, 70-1, 72, 73 in carbon compounds, 17-18, 12 electronic configuration, 11-12*, 45, 46, 58-63, 73-4; 13-14, 33, 34-5, 58-60, 62, 63, 70, 72, 73, 76 Hund's rule, 11-12, 60-2 of a noble gas, 13-14*, 58, 59, 73, 76 periodicity in, 13-14, 35-8 rules for writing, 11-12, 59, 62 electronic structure, 11-12*, 24 and Periodic Table, 13-14, 33-42 electron transfer, 13-14, 59 electron transport chain (ETC), 22*, 44-5, 46, 47, 52, 54, 55, 56 electronvolt, 9*, 11, 13, 33; 10, 45, 46; 11-12, 41 electrostatic force/interaction, 9*, 31, 32, 33, 34, 35; 11-12, 14, 15, 28; 31, 12, 19–20 and stationary electric charges, 9, 31 - 2elements, 11-12, 4-5, 11, 12; 13-14, 5 conservation of, 13-14, 8-9 discovery of, 13-14, 74-5 necessary for life, 25, 20-1 prediction of undiscovered, 13-14, 30-3 rare earth, 13-14, 30, 33 transition, 13-14, 37, 39-40, 41 typical, 13-14, 36 ellipse, 2*, 35, 36 ellipsoidal surface, 1, 13 emigration, 25, 34, 36, 37, 43, 55

emission spectra, 11-12*, 25, 28, 30, 32, 36, 45, 47, 50, 56, 70-1; 31, 3, 14 empirical formulae, 13-14*, 10-15, 16, 17-19, 21, 24 determination of, 13-14, 11-14 Encarsia formosa (wasp), 25, 54 endemic species, 26, 7, 8, 17 endoplasmic reticulum, 22*, 38, 39, Plates 4, 5; 26, 15 endothermic reactions, 16*, 4, 5-6, 10, 22, 23 energy, 9, 1-5; 23, 14 atomic, 31, 3-5, 11-17, 21-2 in heavy atoms, 31, 15-16 in hydrogen atom, 31, 3-4, 11-14, 15-16, 21, 22 barrier, 16, 23, 27 changes and atomic spectra, 11-12, 27, 28-9, 31-2, 36 chemical, 9, 3, 4, 5 continuum, 11-12, 33 dimensions of, 9, 10, 13 electrical, 9, 4, 5, 6-7, 23, 30-5 electromagnetic radiation of, 10, 42-9, 51, 53 from Sun, 10, 4, 53 of the environment, 27, 35, 36; 28-29, 66 flow in aquatic ecosystems, 25, 16-17; 26, 12 in atmosphere, 28-29, 71, 72 diagrams, 25, 13, 14, 16-17 light, 9, 4, 5-7, 12 in living organisms processes requiring, 22, 9-10 supply, 22, 10-11 transmission, 22, 11-12 see also adenosine triphosphate; glucose mass and, 31, 24, 27; 32, 6 nuclear binding, 31, 23, 25, 27, 29, nuclear levels, 31, 21-2 in particle physics, 32, 6-7, 9 scale of, 32, 7 units of, 32, 7 of photons, 11-12, 39-40; 30, 7, 8, 13 potential, 9, 2; 31, 7 released by earthquakes and explosions, 5-6, 20, 89-90; 9, released in nuclear reactions, 31, 29, 30-2, 37-41; see also nuclear power sound, 9, 3, 5 strain, 9, 3, 5; 23, 14 transfer of, 9, 4, 8, 9-10, 35 units of, 9, 11, 12 see also activation energy; atomic nucleus; bond dissociation energy; conservation of energy; electron energy; energy conversion; energy levels; flow diagrams; glucose; gravitational energy; internal energy; ionization energy; kinetic energy; nuclear energy; production ecology; Sun energy conversion, 9*, 2, 14, 15, 16, 18-19, 23, 32, 34, 35

energy of the environment, 27*, 35, 36; **28-29**, 66 energy levels, 30, 4; 31*, 7 diagram, 11-12, 29-35, 47, 51 see also atomic energy levels; electron energy levels; nuclear energy levels energy transducer/transduction: role of ATP, 22*, 11-12 environment changes in, 21, 5, 9, 10 speciation, 21, 22-4 and colour forms of moths, 19, 16-19, 20, 27-9, 30 and fitness, 19, 23, 24 human differences, 21, 11 issues, 25, 22-5, 27, 29, 30, 31, 32, 63 polluted, 15, 31-3; 21, 5, 9, 10 halocarbons and ozone layer, 17-18, 15-16 see also ecology; ecosystems; habitat enthalpy of reaction (ΔH) (enthalpy changes), 16*, 4, 5, 6, 7-15, 22, enzymes, 17-18*, 64, 75, 88; 19, 9; 22*, 6, 24, 25, 26-37; 24, 9; 26, 8, 9-10, 11, 17, 18 in DNA repair, 24, 41 protein role in protein synthesis, 24, 31 nature of, 22, 20, 25 in red cells, 23, 20, 24 salivary amylase, properties of, 22, 33-5, 37, Plate 3 temperature and pH, 22, 28-30 enzyme activity, 22*, 28; 26, 17, 18 temperature and pH effects, 22, 28-30 enzyme assay, 22*, 32 plasma, 22, 32, 35 salivary amylase, 22, 33-5, 37, Plate 3 enzyme catalysis, 22*, 25, 26, 33; 23, enzyme specificity, 22*, 25, 27 enzyme-substrate complex, 22*, 26-7, 30 Eocene Period, 28-29, 20-1, 23 epicentral angle, 5-6*, 61, 62-3, 64-5, 68-9, 74 epicentre of an earthquake, 5-6*, 14, 16, 61-2, 90 epidermis of leaf, 22, 64, Plate 8 equality, proportionality converted into, 2, 41 equilibrium see chemical equilibrium equilibrium constant, 15*, 21, 22-4, 25, 36, 38; 16, 18-19, 28, 29 generalized form of, 15, 34-6 size of, 15, 22-4 temperature and, 15, 12, 39 'equilibrium game', 15, 37 equilibrium system trying to beat, 15, 15-16 water as, 15, 25-7 equilibrium yield, effect of temperature and pressure on, 16, 31-2

equinox, 1, 16

Eras, geological, 28-29*, 4, 25

see also Cainozoic; Mesozoic;

Palaeozoic; Precambrian

Erastosthenes: measurement of Earth radius, 2, 14-16, 17-19, 20, 44-5 erosion, 5-6*, 8, 79; 7-8, 5-6, 7; 27*, 5, 20, 34, 37, 52-3, Plate 2; 28-29, 19, 22 by ice, 27, 39-40, 44, 45; 28-29, 74 by wind, 27, 39-40, 44, 45 see also transportation; weathering error bars, 3*, 29; 4*, 22, 23, 24 errors, systematic, 3, 25, 26; 4, 18-19 see also uncertainties Escherichia coli, 22, 8, 13; 24, 6, 30 insulin manufacture and, 24, 48 virus infection, 24, 6 esters, 17-18*, 63, 64, 69, 70; 22, 15-16 hydrolysis, 17-18, 64, 75 polymerization, 17-18, 82 synthesis, 17-18, 68, 74 ester group, 17-18, 63, 69, 70 estimating uncertainties, 4, 19-20 ETC see electron transport chain ethanamine see ethylamine ethane, 17-18, 18-19 comparison with ethylene and acetylene, 17-18, 37 structure, 17-18, 27 ethane-1,2-diol, 17-18, 82 ethanoic acid see acetic acid ethanol (alcohol), 13-14, 57; 17-18, 9; 22, 15-16, 31, 57 chemical reactions, 17-18, 63, 67-8, 71-2 molecular model of, 17-18, 25 as motor fuel, 25, 11 physical characteristics, 17-18, 22 - 3ethene see ethylene 'ether' see ethoxyethane ethers, 17-18*, 4, 32 chemical reactions, 17-18, 69, 70 structural isomerism, 17-18, 32, ethoxyethane ('ether'), 17-18, 35 ethyl acetate, 17-18, 63, 67-8; 22, 15-16 ethyl alcohol see ethanol ethylamine, 17-18, 21 ethylene, 17-18, 37, 38, 39, 43 polymerization of see addition polymers ethyl methyl ether, 17-18, 32 ethyne see acetylene Eucalyptus, 25, 4 eukaryotes, 19*, 9, 11; 20, 8; 21, 29; 24, 44, 45 time when appeared, 28-29*, 59, 64, 70; 32, 45 Europe climate changes, 7-8, 21 igneous rocks, 7-8, 65 mountains, 7-8, 22, 24-5 rift valley, 7-8, 29 see also Britain; Iceland European Organization for Nuclear Research see CERN eustatic changes, 28-29*, 76, 79 eutrophication, 25*, 27, 29, 33 evaporites, 27*, 41, 45 evolution by natural selection, 1, 8; 17-18, 91; 19*, 11, 12-14, 15, 29, 30-7; 20, 31; 21, 6-8, 10, 12, 13, 21, 23; 23, 14, 21; 24, 4,

evolution (continued) mutation and, 19, 31 fatty acids, 22*, 7, 15, 16, 32, 43, 60, 61, 64 neutral, 21, 15 9; 26, 6-8, 13, 14, 17; 28-29, faults, 5-6*, 14, 15, 22, 27, 90, 92-3; 8-12, 13 see also evolution by natural 7-8, 43, 73-4; 27*, 48, 54 adaptation: relation between selection see also transform faults fixation, 21*, 8, 10, 11; 26, 17 structure and function, 19, 13-14, 15; **22**, 20, 29 and classification, **21**, 27-34 faunal succession, principle of, 28-29, fixed relationships, graph 15-19, 25 representing, 2, 37, 41 Fawcett, E. W., 17-18, 79 fixed-target experiments, 32*, 9, 10 evolutionary trees, 21, 28, 33 fecundity, 19*, 21, 23, 24, 32 flame spectroscopy, 13-14, 74, 75 and genetics, 21, 4-10 case studies of, 21, 9-10 reduced in control of pests, 25, 55 flatworm: oxygen supply, 23, 6-7, 10 Mendelian, 21, 3 see also reproduction flavin adenine dinucleotide see FAD feedback loop, 23, 29; 26, 11, 18 flavoprotein, 22, 45, 52, 55 phenotypic and genotypic changes during, 21, 4-6 feldspars in rocks, 27*, 6, 9-11, 14-16, 23, myxomatosis spread by, 25, 61 recessiveness and dominance, 21, 29, Plate 6 oxygen supply, 23, 8 4, 6-8, 10, 17 see also genetic variability in meteorites, 28-29, 51 Flemming, Walther, 20, 8 implications of theory, 19, 36-7 transport and deposition of, 27, 36 flies, fruit- see Drosophila modelling, 19, 32-6, 37 flints, 28-29, 20-1 weathering, 27, 32, 33 speciation, 21, 22-7; 28-9, 72 fermentation, 22*, 57 flood explanation of fossil sequences, taxonomic hierarchy, 21, 27, 29-32 Fermi, Enrico, 31, 39 28-29, 16 Fermilab, 32, 10, 36 flow diagrams see also mutation ferns, time when appeared, 32, 45 energy, 25, 13, 14, 16-17 evolution of atmosphere, 28-29, 57-8, 61 ferromagnesian minerals, 27*, 9, of heating system, 23, 28, 29 evolution of Universe, 32, 44-5 10-11, 15-16, 18 flowering plant, life cycle, 22, 4 evolutionary tree, 21*, 28, 33 weathering of, 27, 32, 33 fluorides, 13-14, 53, 59 fluorine, 11-12, 22, 24, 64, 72, 73; exchange of alleles see crossing over see also iron in rocks; magnesium 13-14, 25, 58, 73 exchange particle see gauge bosons in rocks excited nucleus, 31*, 31, 32, 36; 32, 27 fertilization see cross-fertilization; in atmosphere, 28-29, 56 in carbon compounds, 17-18, 8, 9, excited state of an atom, 11-12*, 32 gametes excited states of hadron, 32, 27 fertilizers and biogeochemical cycles, 10, 13, 15, 20 25, 28, 29, 30, 32 chemical bonding, 13-14, 59-60, exercise and blood system, 23, 15-18, Feynman, Richard, 10, 52; 32, 25 20, 32, 33 65 exons, 24*, 44, 45, 47 fibres, synthetic, 17-18, 4, 40, 78, 82, as molecular covalent substance, 86, 87, Plates 3, 9 and 10 13-14, 56 exothermic reactions, 16*, 3, 4-6, 9, 16, 17, 18, 24, 29, 32, 33 fibrous proteins, 17-18*, 88; 22, 23 physical properties, 17-18, 11-12 experimental data, 1*, 20 field fluoroalkanes bonding and molecular structure, experiments, doing see practical dipole, 5-6, 70 work lines, 5-6, 43, 45-6, 47, 48 17-18, 8 strength, geomagnetic, 5-6, 49-51, homologous series, 17-18, 19, 20 explosions, 5-6, 89-90 54, 55-6 physical properties, 17-18, 10-11, explosive rocks, 5-6, 77 field notes, 4, 7, 8 13, 14-15 explosive volcanic activity, 7-8, 15, 16; 27, Plate 10 field of force, 5-6*, 43 structural isomerism, 17-18, 28 exponential decay, 11-12*, 21, 23; filial generations see first filial; 1-fluorobutane, 17-18, 19 second filial fluoroethane, 17-18, 19, 28 28-29, 27 finches in Galápagos Islands, 26, 6-8, exponential growth, 19*, 21 1-fluorohexane, 17-18, 19 14, 17 fluoromethane extended covalent substances, 13-14*, fins and flippers as an adaptation, 19, bonding and molecular structure, 63-4 extinction of species, 28-29, 68, 72, 81 13 **17–18**, 8, 9, 28 fire extinguishers, 17-18, 15, 16, Plate physical properties, 17-18, 10-11, extracellular fluid, 23*, 6 extrapolation, 2*, 39; 4, 11 as refrigerant, 17-18, 14-15 extraterrestrial factors and ice ages, fire fountains, 27, 19, Plate 10 28-29, 5, 77, 78 first carnivores, 25*, 11, 12, 14, 18 1-fluoropentane, 17-18, 19 extrusive (volcanic) rocks, 5-6*, 8, 77; first filial generation (F1), 20*, 4, 6, 1-fluoropropane, 17-18, 19, 28-9 27, 19-20, 52-3, Plates 2, 3 23, 27-8, 33, 37, 38, 40, 41, 42, 2-fluoropropane, 17-18, 28-9 see also igneous rocks 44 foam-blowing agents, 17-18, 15, 16 first ionization energy, (I1) 11-12*, eye, lens of human, 10, 30-1 focus of an earthquake, 5-6*, 14, 36, 38, 89 62, 63-6 fish, 25, 16-17; 26, 12, 13, 19 folding/folds of rocks, 5-6*, 12; 7-8, adaptation by, 19, 13-14 22, 70; 27*, 49, 54 excretion, 23, 23 food fecundity of, 19, 21 FAD (flavin adenine dinucleotide), and glucose level in blood, 23, 25, 22*, 31, 32, 36, 46, 51, 52, 53, oxygen supply, 23, 8-9, 10 26 54, 55, 57 time when appeared, 28-29, 12; 32, production, 19, 4 faecal matter, 25, 13, 14, 18 as source of energy, 9, 3, 12 food chain, 25*, 11, 12, 18; 26, 12 water pollution and, 25, 27, 30, 32 Fahrenheit temperature scale, 9, 23-4 foodstores, 22, 12 falsifiability criterion, 1*, 7, 8, 43; Fisher, Reverend Ormond, 7-8, 17 7-8, 80 fission reaction, 9, 4 in animals, 22, 16, 17 family, 21*, 29, 31, 33; 26, 3, 15 in plants, 22, 16, 17, Plate 6 see also nuclear fission fissure eruption, 27, Plate 10 food web, 25*, 12, 13–15, 16–17, 18 aquatic, 25, 16; 26, 12, 18–19 Faraday, Michael, 13-14, 46 fitness, 19*, 19, 20, 32–6, 37; 21, 8, 10, 12; 26, 6, 8, 13 fat hen (weed, Chenopodium album), fool's gold see pyrite

actual and potential, 19, 22

fecundity and viability, 19, 21-4

differences in, 21, 6

acceleration and, 3*, 9-10, 11,

14-15, 20

25, 36 fats, 22*, 7, 15, 16

transport of, 23, 11

catabolism of, 22, 60, 61; 23, 26, 27

forces (continued) balanced, 3, 10 constant, energy transferred by, 9, 9-10 driving for continental drift, 7-8, 23, 24, 25-6 for plate motion, 7-8, 76-8 of gravitational attraction, 3, 22 magnitude of, 3, 22, 23 between molecules see intermolecular forces see also convention currents foreshocks, 5-6*, 18 forests and woodland acid rain and, 25, 30, 32 and carbon dioxide, 28-29, 58, 78 cleared, biogeochemical cycles and, 25, 23-4, 27, 31 communities, 25, 59-60 ecosystems, 25, 3, 5, 9, 18 form see morphology formaldehyde, 17-18, 39, 40, 92, 93 formic acid (methanoic acid), 17-18, 39, 40 formulae see chemical formulae; empirical formulae; molecular fossil fuels see fuels fossils, 5-6*, 4; 28-29*, 6, 8-12, 13; 7-8, Plate 3 climatic changes and, 28-29, 74 and dating rocks, 28-29, 8, 11, 13, 24, 34 evidence for landbridges and continental drift, 7-8, 18, 19, 20, 24, 28, 57-8 microfossils, 27, 40, 41 recent discovery, 28-29, 81 and source of atmospheric oxygen, 28-29, 54-5, 64-70 in Stratigraphic Column, 28-29, 11, 12, 13, 14, 18, 24, 25 see also faunal succession Foucault, Leon, 1, 42 Foucault pendulum experiment, 1*, 27, 28, 32, 42 foxes, 25, 62 in food chains and food webs, 25, 11-12, 14-15 fractional crystallization, 27*, 22, 23, 24, 29 fracture zones, 7-8, 54, 64 fragmental texture, 5-6*, 8 Fraunhofer diffraction, 10*, 30, 31 Fraunhofer, Joseph, 11-12, 26 Fraunhofer lines, 11-12*, 26, 27, 70 free-fall experiments, 3, 19, 24, 39 free particle (quantum), 30*, 10, 21, 22, 23 and diffraction, 30, 10-11, 14 and infinite sine wavefunctions, 30, 22, 23 propagation of see de Broglie's formula; wavefunctions Freons, 17-18, 9, 15 frequencies and atomic spectra, 11-12, 26, 29, of electromagnetic radiation, 10, 39, 40 threshold, 10, 43, 44, 47 frequency of a wave, 10*, 13, 16, 23 frog hearts, 23, 35-6

frontiers of geology, 28-29, 80-1 frost shattering, 27, 31-2, 34, 44 fructose, 22, 43; 23, 25 fruit-fly see Drosophila Fucus vesiculosus (seaweed), 25, 57 chemical, 16, 14, 15-16 ethanol from sugar cane, 25, 11 fossil, 25, 10, 23 combustion of, 16, 2, 3, 15, 16; 25, 22-4, 30, 31, 32; 28-29, 56, metabolic, 22, 43, 60 rocket, 16, 33-5 see also power fumaric acid, 22, 45 function and structure, relationship between, 19, 13-14; 23, 14, 21 functional groups, 17-18*, 10, 22, 31-3, 38, 39, 42, 70, 97 chemical reactions, 17-18, 67-77 functional isomers, 17-18*, 31, 32 functional proteins, 24*, 38 fundamental interactions, 32*, 4 mediation of see gauge bosons range, 32, 16, 29 see also electromagnetic; gravitational; strong (between quarks); weak fundamental niche, 25*, 59, 62 fundamental particles, 32*, 3, 15, 43 time (after Big Bang) when formed, 32, 44-5 see also gauge bosons; lepton-quark symmetry; leptons; quarks fungi, 21, 29 food chains and food webs and, 25, 11, 13-14 as heterotrophs, 22, 8, 38 nitrogen cycle and, 25, 26

G

G see guanine G (gravitational constant), 3, 34 gabbro, 5-6*, 60, 76, 79, Plate 14; 7-8, 5, 9; 27*, 17, 24; 28-29, 4 density, 27, 37 and metamorphism, 27, 51 and plate margins, 7-8, 63, 64, 65, 66, 72, 73, 78 Galápagos Islands, 26, 6-8, 14 Galileo, Galilei, 2, 5, 35, 42-3, 44; 3, 4, 8-9; 7-8, 32 inclined planes experiments, 3, 8-9 gall bladder, 26, 10 gall wasp (Andricus quercus-calicis), 25, 59 gametes, 19*, 10; 20*, 8-9, 11, 17; 21, 4, 14, 20-1; **24**, 4, 7; **26**, 15, 16, DNA content of, 24, 8 fusion of see fertilization human, 20, 8, 9, 11 and mutation, 24, 40, 43 production of, see meiosis radiation damage to, 31, 34 see also egg; ovule; ovum; pollen; sperm

fusion see fertilization; nuclear fusion

γ-decay, 11-12*, 18, 20, 23; 31*, 31, 32, 34, 36 y rays (y radiation), 10, 40; 30, 6 scattering of, 30, 8 garnets, 27, 15, 16 gas chromatography, 17-18, 19, 49 gases, 11-12, 7, 9-10, 13; 13-14, 25, atomic spectra, 11-12, 28-36 chemical bonding, 13-14, 58-64, 67 and chemical reactions, 16, 7-8, 13, combustion, 16, 2, 15, 16, 17 rates of reaction, 16, 18, 20, 22-5, 26-7 internal energy of, 9, 28, 29, 30 reactions of, 13-14, 18-19 ionization, 11-12, 7, 38, 39, 64 isotopes, 11-12, 11, 12, 15-17, 20, magnetic properties, 11-12, 53, 54, 55 see also air; atmosphere gastric juices, 26, 10 gastropods, 28-29, 67, 68, 70, Plates 21 and 30 gauge bosons, 32*, 4, 5, 38, 43, 44 as mediators of fundamental interactions, 32, 38-9 properties of, 32, 21, 22, 39 types of, 32, 39-42 see also gluons; graviton; intermediate vector bosons; photon Gay-Lussac's law, 13-14*, 18, 19 Gell-Mann, Murray, 32, 22, 26, 28, 29, 31, 41 genes, 19*, 9, 11; 20*, 23-30, 33-40, 45-51; 21, 14, 19-21, 22; 22, 4-5, 6, 20, 23, 24; 24*, 4, 7, 16, 42-4, 46-7; **26**, 3, 5, 8, 13, 15, 16 control, 24, 16 damaged by ionizing radiation, 24, 40; 31, 34, 35 independent assortment and, 20, 33-40 linkage of, 20, 40-4 mitosis and, 20, 45-51 model of inheritance and, 20, 23-30 split, 20, 50; 24, 44, 46-7 structural, 24, 42 see also chromosomes; DNA; genetic variability; heritable character; inheritance; recombination gene pool, 21*, 4, 5-6, 8-9, 10, 21, 26; 26, 17 general theory of relativity, 32, 15 generations length of, 22, 5 see also filial generations genetic code, 24*, 26, 35-9, 45 deciphering, 24, 36-8 non-overlapping, 24, 38 table, 24, 36; 26, 9 triplet nature of, 24, 29, 35-8 universal, 24, 38, 46, 49 genetic drift, 21*, 15, 22 genetic engineering, 24*, 45, 46-9 genetic fingerprinting, 24*, 45 genetic variability within

populations, 21, 11-22

GENETICS

genetic variability (continued)	glucose, 17–18, 62, 89; 22*, 15, 17;	plotting, 4, 9–15, 24
animal, 21, 13–15	26 , 9, 12, 15, 18	representation of uncertainties, 4,
balanced polymorphism, 21, 16-19	catabolism, 22, 15, 27, 41, 43,	22–3
human, 21, 11–15	44–54, 58–9, 61	scale, choosing a, 4, 13, 14–15, 24
neutral mutations, 21, 15–16	combustion of, 16, 15	grass,
recombination, 21, 19–21, 22	levels in blood, 23, 11, 14, 24–8; 26,	copper tolerance of, 21, 9, 10
genetics see gene pool; genes;	12, 18	effect of rabbits on, 25, 61, Plates
genetic; mutation and under	control of, 23, 31-2	11 and 12
evolution	low and high, 23, 26, 28	grasshopper chromosomes, 20, 18,
genome, 20*, 24	regulation of, 23, 25, 27	19–20
genotypes, 20*, 25, 28-9; 21, 4-6; 24,	polymers of, 22, 17-18, 19	grating, diffraction, 10, 9, 10, 33-6;
4; 26, 5, 6, 17	glucose residues, 22*, 18, 19	30, 6, 7, 11
genus (plural genera), 21*, 29, 30, 33;	gluons, 32*, 39, 41, 42, 43, 44	gravitation, Newton's law of, 2, 36; 3,
26, 3, 15	glutamic acid (Glu), 17-18, 62; 22,	35–7; 9, 32
geocentric dipole, 5-6, 47, 48, 55	21, 30, 45; 24, 36, 40	gravitational constant, G, 3*, 34
geocentric model of the Universe, 1*,	glutamine (Gln), 22, 21; 24, 36	gravitational energy, 9*, 2, 5, 13-15,
14, 44	glycerol, 22*, 7, 15, 16, 43, 45, 60; 23,	22
geocentric system, 2, 33	26	conversions to and from, 9, 2, 14,
geographic poles, 5-6, 44, 49, 55-6	glycidol, 17-18, 64, 67	15, 16, 18–19, 23, 32
geographical isolation, 21*, 23, 24,	glycidyl butyrate, 17-18, 63, 64, 65,	formula for, 9 , 13
26–7; 26 , 8, 13	67, 95	gravitational force, 9, 32
geological cycles, 27, 4-5; 28-29, 22	glycine (Gly), 17-18, 60, 92; 22, 21,	of attraction, 3, 22
geological map, 28–29 , 18–19	45; 24, 36; 26, 9, 18	gravitational interaction, 31, 11,
geological section, 28–29, 18–19,	glycogen, 22*, 15, 17, 18, 19, 24, 43,	19–20; 32 , 4; see also
20–1	45; 23 , 24, 25, 38; 26 , 18	
geological time see time		gravitational force
	breakdown to glucose, 23, 26, 27,	gauge bosons, 32 , 15, 38, 39, 42
geology, 5–6, 4, 5	28	hadrons, 32, 18–19
frontiers of, 28–29 , 80–1	glycogenolysis, 23*, 26, 27, 28	leptons, 32, 15–16, 35
see also Earth sciences; rocks	glycolysis/glycolytic pathway, 22*,	quarks, 32, 28, 29
geomagnetic field strength, 5-6,	44, 45, 47, 49–50, 54, 57, 60	graviton, 32*, 39, 42, 43
49–51, 54, 55–6	glycosidic bonds, 22*, 18, 19, 20	gravity, 3*, 18
geomagnetic poles, 5-6*, 41, 44, 47,	gneiss, 27*, 49, 51, 52, 53; 28–29, 4,	acceleration due to, 3, 18, 19, 21,
48, 49, 50, 51, 55, 83–4	18, 20–1	24–31, 33–6; 5–6 , 10
geometric isomers/isomerism, 17–18*,	gold, 11–12, 5, 13–14; 13–14, 30, 76;	force of, 3, 18, 20
42, 43, 44, 45	27 , 6; 28–29 , 53	free fall under, 3, 19, 24, 39
applications, 17–18, 46–51	gold foil experiment, 11-12, 13-18,	mass and, 3, 18–22
geometric variations in Earth's	32, 24	as mechanism for plate motion,
orbital and axial rotations,	Gondwanaland, 7–8, 21, 25; 28–29,	7–8 , 78
28–29 , 70	80	weight and, 3, 20-1, 23
geometry, spherical, 7–8, 55	Gorda Ridge, 7–8, 42, 73	gravity anomalies, 7–8*, 22, 32, 34–5,
geopoetry, 7-8, 38-40	GPP see gross primary production	36, 58, 69, 77
Geospiza (ground finch), 26, 6–8	graded bedding, 28-29*, 8, 14	and isostatic equilibrium, 7-8,
G. conirostris, 26, 7–8, 17	gradient, physical, on shore, 25, 57,	31–2
G. difficilis, 26 , 7–8, 17	68	and earthquakes, 7-8, 34-6
G. magnirostris, 26, 7-8, 17	gradient of a straight-line graph, 3*,	and plate margins, 7-8, 69-70, 77
geothermal power, 7–8, 69	30	grazing see herbivores
germanium, 13-14, 28, 37-8, 69	grain size of rocks	great tit (Parus major) populations,
germ cells see gametes	igneous	25, 34, 35–6
Germer, Lester, 30, 11	coarse, 27, 22-4, 29	greenhouse effect, 25*, 25, 31; 28-29*,
giant molecules, 17-18, 77-91; 19, 10	fine, 27 , 19–20, 29	72, 78
addition polymerization and,	metamorphic, 27, 49	gross primary production (GPP), 25*,
17–18 , 78–81	transport and deposition, 27, 35-6,	8, 9, 13, 15, 18; 26 , 12
biological macromolecules, 17-18,	38, 43, 45; 28–29 , 14	in aquatic ecosystems, 25 , 16–17
88–90	granite/granitic rocks, 5-6*, 8, 60, 77,	ground state of an atom, 11–12*, 32
condensation polymerization and,	79, 81, Plates 9 and 10; 7–8, 5,	
17–18, 81–3, 89	9, 73; 27* , 28–9; 28–29 , 4,	Groups in the Periodic Table,
physical properties of, 17–18, 84–7		13–14*, 27, 36
structures of, 17–18, 78	20–1, 42, 47	group transfer molecule see
	composition of, 27 , 9, 11, 17, 18,	coenzymes
synthesis of, 28–29, 62, 63 Cibbs Frosture Zone 7, 8, 51	29, Plates 4 and 6	growth, 22, 5–12; 26, 4
Gibbs Fracture Zone, 7–8, 51	formation of, 27 , 24, 28–9, 52–3	see also energy; survival
Gibson, R. O., 17–18, 79	metamorphism and, 27, 51, 52, 53,	guanine (G), 17–18, 89; 24*, 10, 11–12
gigaelectronvolt (GeV), 32, 7, 12	54	guard cells, 19 , 6–7; 22 , 63
gills, 23, 8–9, 10	and origin of continents, 27, 28–9,	Gurdon, John, 24, 15–16, 50
glaciation see ice ages	52–3	gypsum, 27, 41, 45; 28–29, 20–1
glacier, 27, Plate 14	radiometric dating and, 28–29, 33,	
glands, 23, 31, 32, 36	34, 35	
see also hormones	weathering of, 27, 33	Н
Glashow, Sheldon Lee, 32, 31, 34, 40	graphite, 13-14, 64, 69-70; 27, 11	
glassy texture, 5–6*, 8	density of, 5-6, 66	Haber, Fritz, 16, 30
globin, 23*, 19	graphs, 2*, 36, 37-9, 41; 4, 9-15, 22-4	Haber-Bosch process, 16, 2, 30-2;
globular proteins, 17-18*, 88, 89; 22,	axes of, 2, 37, 38, 39	22 , 26; 25 , 28–9
23–4, 25; 26 , 10, 18	exponential, 11-12, 20; 19, 21-22;	habitat; 25*, 3, 5, 6, 59
see also enzymes	28–29 , 27	hadrons, 32*, 18, 19-25, 31-4
glucagon, 23*, 27, 28, 31, 32; 26, 18	gradient, 3, 30	baryon number, 32, 20, 21-2, 23-4,
gluconeogenesis, 23*, 26, 27	logarithmic, 28-29, 28-29	32

high-energy physics, 32*, 4 hadrons (continued) Heisenberg's uncertainty principle, high-grade metamorphism, 27, 51, 54 30*, 4, 23, 26-8, 29-31, 32, 34; charge, 32, 19-20, 22, 24, 25 charmed, 32, 34 31, 6 applied to atoms, 30, 29-31 constituents of see quarks and applied to macroscopic objects, 30, antiquarks distinct from leptons, 32, 18 18 families of, 32, 18-19 applied to quanta, 30, 26-9, 31 not fundamental particles, 32, 24-5 heliocentric model, 1*, 32, 44, 45 strangeness, 32, 22, 23-4, 32 helium, 11-12, 5, 13 table of, 32, 22 in atmosphere, 28-29, 52, 55, 57 time (after Big Bang) when formed, discovery of, 13-14, 75 32, 44-5 electronic configuration, 11-12, 46 haem, 22*, 24, 25, Plates 1 and 2; 23, first ionization energy, 11-12, 64 19 inertness of, 13-14, 58 haematite, 28-29*, 63 nucleus haemocyanin, 23*, 12 binding energy of, 31, 23 haemoglobin, 21, 16-19, 22; 22*, 20, formed by nuclear fusion, 31, 39, 24, 25, Plate 2; 23*, 11, 18-22; 24, 9 orbital, 11-12, 59-60 35, 81 mutation and, 21, 16, 19; 24, 40 photoelectron spectrum, 11-12, 41 hepatic portal vein, 23*, 25 haemoglobin A, 21, 16, 19 haemoglobin S, 21, 16, 19 heptane, 17-18, 19 solubility of alcohols in, 17-18, 23, see also sickle-cell anaemia haemophilia, 19, 31 24 Hahn, Otto, 1, 5; 11-12, 22-3 heptan-2-one, 17-18, 48 herbivores, 22, 18; 25*, 11, 33; 26, 18 Haldane, J. B. S., 17-18, 91, 92 half-life of protein, 22, 5 biogeochemical cycles and, 25, 22, half-life in radioactive decay, 11-12*, 20, 21, 22, 23; 28-29*, 26-31 food chains and food webs and, 25, halides, 13-14, 60, 72, 73 11 - 14, 18halite, 27, 41, 45 killed by insecticides, 25, 53 population density, 25, 34–5 rabbits, control of, 25, 60–2 haloalkanes, 17-18, 70 halocarbons, 17-18*, 13, 14-16 halogens, 13-14*, 25, 59, 60, 72, 73 heredity see heritable character; 15, 16 in carbon compounds, 17-18, 8, 9, inheritance 10, 13, 15, 20 'Hering-Breuer reflex', 23, 33 heritable character, 19*, 27, 29, 30, 37 discovery of, 13-14, 75 inertness of, 13-14, 58 and population changes, 19, 25-9 see also inheritance physical properties, 17-18, 11-12 Herodotus, 28-29, 8 'handedness' see chirality Hershey, Alfred, 24, 7 hand lens, use of, 5-6, 8 76 haploid number of chromosomes, 20*, Hertz, Heinrich, 10, 13, 39 11, 12, 17, 24, 25-6; 26, 15 hertz, Hz, 10*, 13, 23 'hard' water, 27, 40 Hess, Professor Harry, 7-8, 26, 38-40, 43, 44, 46, 47, 81 hares, 25, 62 Hawaii, 7-8, 68, 77 Hess, W. G., 16, 11 Hess's law, 16*, 11, 14 heart, 23, 12-14, 20; 26, 12 horizontal beat, control of heteropolymers, 17-18*, 78, 89; 22, hormonal, 23, 35-7 17, 20-1 74 nervous, 23, 33-5, 37 heterotrophs, 22*, 8, 9, 10, 11, 13, 38, 39, 61, 64, 65; 23, 4; 26, 12, 18 blood system and, 23, 12-14 effect of exercise on, 23, 15-18, 20 biogeochemical cycles and, 25, 22, frog's 23, 35-6 pig's, 23, 12, Plate 9 production ecology, 25, 7, 9, 10, 31-2 see also cardiac output 11 - 15heat, 9*, 3, 6, 35 heterozygosity, 21*, 3, 4, 10, 13; 24, accretional, 28-29, 48-9 balanced polymorphism, 21, 17, 19 and chemical reactions, 16, 3-7, 20 in living organisms, 22, 10, 11, 65; genetic variability, 21, 12, 13-14, 15 recessiveness and dominance, 21, 23, 11, 23-4 6-7, 8 from respiration, 22, 10, 12; 25, 7, recombination and, 21, 20-2 8, 9, 14-15, 17 specific, 9, 25, 26, 29 heterozygous, 20*, 27, 32, 41; 26, 5, transfer, 9, 24, 25-9, 35 16 hexan-1-amine, 17-18, 21, 22 34 in body, 23, 11, 23-4 hexane, 17-18, 19 see also heat-flow; temperature hexane-1,6-diamine, 17-18, 82, 96 heat flow, 28-29, 26 hexanedioic acid, 17-18, 82, 96 generated at plate margins, 7-8, hexanoic acid, 17-18, 70, 96 45 66, 72, 79 hexan-1-ol, 17-18, 20, 23, 24 hex-2-enal, 17-18, 48-9 oceanic, 7-8, 36-7, 58 heating of planets, 28-29, 47-50 hierarchy, taxonomic, 21, 27, 29-32 heavy atoms, energy levels of, 31, 15-16 high-density (low pressure) polymer, 17-18, 85, 91 Heisenberg, Werner, 30, 28, 29

higher carnivores, 25*, 11, 12, 14, 18, higher-order structure of proteins, 22*, 22, 23-4, 29; 26, 10, 17, Himalayan margin see continent/ continent collision histidine (His), 22, 21; 24, 36 histogram, 7-8, 9 histones, 20*, 9, 10, 21 see also chromatin history of science, 7-8, 79-81 holly leaf miner: mortality factors and k-value analysis, 25, 45-53, Plates 5-9 Holmes, Arthur, 5-6, 84; 7-8, 25-6, Holocene Period, 28-29, 23 homeostasis, 23*, 28, 29, 31-2, 35, 37, 38; 26, 11, 12, 14, 18 in carbon cycle: oceans as buffers, 25, 23, 24, 25 hominids (Hominidae), 21, 31; **28–29***, 7, 12, 17 Hominoidea, **21**, 31, 32 Homo sapiens, 28-29, 72 time when appeared, 21, 31; 32, 45 see also humans homogenate, 22*, 40, 41 homologous pairs of chromosomes, 20*, 13, 14, 18-20, 24-6; 26, crossing over in, 20, 24 inheritance of more than one character, 20, 33-6 pairing mechanism, 20, 19 homologous series, 17-18*, 18, 19-22, 38; 22, 16 chemical properties, 17-18, 67-8, homopolymers, 17-18*, 78, 89; 22, 17 homozygous, 20*, 27, 28, 41; 24, 42-3; 26, 5, 16 Hooke, Robert, 19, 6 rock movements, 7-8, 24-5, 43, 73, strata, 28-29, 24 hormone proteins, 22, 20 hormones, 23*, 26; 24, 9, 46; 26, 12, and blood glucose level, 23, 27, 28, circulation of, 23, 11 and control of heart beat, 23, 35-7 see also insulin hornfelses, 27, 50 humans, 19, 5-6, 11 activity, 26, 14 chromosomes, 20, 9, 18, 20-1 diseases, 20, 20-1; 21, 12, 14, 16-19; 23, 26, 27; 24, 46; 25, gametes, 20, 8, 9, 11 genetic variability, 21, 11-15 genus Homo, 21, 31; 28-29, 72; 32, life cycle, 22, 4 population growth, 25, 34 recombination and, 21, 20, 21 survival of, 19, 21 time when appeared, 32, 45

Hund's rule, 11–12*, 60, 61–2 Hutton, James, 27, 4, 5; 28–29, 19,	hydrogen chloride, 13–14, 19, 56, 76 chemical bonding, 13–14, 61, 66–7 dipole–dipole forces in, 17–18, 12
Huygens, Christiaan, 10, 3	gas, 15, 6, 8
Huygens' construction, 10*, 25, 26, 27,	valency, 13-14, 21-2
28–30	hydrogen cyanide, 17-18, 92, 93; see
hyaloclastics, 7–8, 69	also cyanide compounds
hybrids, 21, 25	hydrogen iodide, 15, 3, 34
sterility of, 21 , 26 hydrides, 13–14 , 26–7, 28	hydrological cycle, 25, 21; 27*, 4, 53 hydrolysis, 17–18*, 75, 88; 26, 11, 18
hydrocarbons, 17–18*, 7	of fats, 22, 16, 32, 60
combustion of, 16 , 2, 15, 16, 17	of glycosidic bonds, 22 , 18, 19
physical properties, 17-18, 22-4	of nucleic acids, 22, 17
saturated, 17-18, 18-19, 22-3	hydrophones, 5-6, 88
unsaturated, 17–18, 37–9, 41–5	hydrosphere, 28–29*, 58
hydrocarbon group, 17–18*, 10 hydrochloric acid, 15, 6, 9, 26; 26, 11	hydrostatic equilibrium, 15 , 12, 14, 16 hydroxides, 13–14 , 49, 63; 28–29 ,
dissociated equilibrium in, 15, 23	52–3
electrolyte, 15, 7, 18–19	hydroxide ions
pH of, 15, 27, 30	as bases, 15, 7, 9, 10
production of, 15, 6	in glucose, 22, 18
hydrogen, 11–12, 5; 13–14, 18, 19, 39,	in glycerol, 22, 15
73, 76; 28–29 , 62 absorption spectrum, 11–12 , 38, 48	in water, 15, 8, 24–6, 33 hydroxyl group, 17–18*, 20
in atmosphere, 28–29 , 52, 55, 57	chemical reactions, 17–18, 67, 69,
atom	70
energy levels of, 31, 3-4, 11-14,	see also alcohols
15–16, 21, 22	hyperglycaemia, 23*, 26, 27, 32; 24,
model of, 31, 4, 11–14	46 hypoglycaemia, 23*, 25
and nuclear fusion, 31, 39, 40–1 visible emission spectrum, 31, 3	hormone see insulin
atomic spectra, 11–12, 28–9, 30–2,	hypothalamus, 23*, 31
35, 36	hypothenuse, 2*, 32
ionization energy, 11–12 , 33, 34–5, 64	hypothesis, 1, 8
binary compounds, 13-14, 21-2	
bomb, 11–12, 23; 31, 39	-
bonding in molecules, 13–14, 60, 61, 67	ICDH see isocitrate dehydrogenase
charge of nucleus, 11-12, 16	ice ages, 28-29*, 72, 75-9
combustion of, 16, 15, 17	ages of, 28–29, 31
emission spectrum, 11–12, 47	as calibration points, 28–29, 32–3,
energy-level diagram, 11–12, 38,	35
43, 47, 59, 70; 31, 3–4, 11–14 first ionization energy, 11–12, 64	causes of, 28–29 , 77–9 Quaternary, 28–29 , 72, 74, 75–6,
ions, 23, 22	77, 78, 79
in acids, 15, 7, 9, 18	sea-level changes, 28-29, 75-7, 79
pH of, 15, 27-8, 29, 30, 33,	see also climate changes
38-9	ice: erosion, transport and deposition
in water, 15, 8, 13, 19, 24–6, 33	by, 27 , 39–40, 44, 45; 28–29 , 74
isotopes, 11–12, 22 lost from Earth, 28–29, 55	ice cap, south polar, effect of, 7-8, 21,
magnetic properties, 11-12, 53, 54,	24
55	see also isostasy
mass of atoms, 11-12, 9	icefish, Antarctic, 22, 29
orbital, 11–12, 15	Iceland
planetary model of, 11–12, 15	omitted from continental fit, 7–8,
in primordial atmosphere, 17–18, 91–2	volcanic activity, 7–8, 66–9
production of, 13-14, 50	ICRP see International Commission
rates of reaction, 16, 28	on Radiological Protection
with bromine, 16, 20, 22-5, 26-7	identifying uncertainties, 4, 16–17
with chlorine, 16, 18–19	igneous rocks and processes, 5–6*, 9,
as reducing agent, 17–18, 71, 73 sources of, in living organisms, 22,	54–5, 76–7, 79, 83; 7–8 , 39; 27 , 5, 17, 18–30, 52–3
8–9	constructive plate margins and
in Sun, 28–29, 46	origin of basalts, 27, 20–1, 25,
water formed from, 13-14, 20	26, 29
hydrogen bonds, 17–18*, 11, 13, 24,	destructive plate margins and
90; 22 , 23; 24* , 11, 13, 17, 18,	origin of andesites, 27, 24–7,
25, 31 in alcohols, 17–18 , 23	28, 29, 52–3 granite and origin of continents,
in DNA, 17–18, 90; 24, 11	27 , 28–9, 52–3
in nylon, 17–18 , 86–7	layered, 7-8, 64, 66, 78

mantle, 27, 17, 18-19, 29 minerals in see silicate minerals and plate margins, 7-8, 63-5, 66, 72, 73, 78; see also constructive plate margins and destructive plate margins volcanoes and volcanic rocks, 27, 19-20, 25, 27-9, 52-3 weathering of, 27, 33-4 see also andesites; basalt; extrusive rocks; granite; igneous rocks; plutonic rocks; volcanic activity Iliopoulos, John, 32, 31, 34 imbalance in the environment, 26, 14 immigration, 25, 34, 42, 55; 26, 14 immunoglobulins, 19, 9 immunoproteins, 22, 20 incidence see angle of incidence incident waves, 5-6, 33-5 inclination, magnetic, 5-6, 48, 49, 82, 83 incompletely dominant alleles, 21, 17 independent assortment, 20*, 33-5, 36, 37-40, 43; 26, 5 independent variable, 4*, 11, 24 Indian Ocean, 7-8, 11, 43, 49 indicators, 15*, 4 indium, 28-29, 46 induced nuclear fission, 31*, 38 induction, 1, 7, 8 infection, protection against, 23, 18 infinite sine waves, 30, 18, 23 as wavefunctions, 30, 19, 21, 22, 33 influenza, 19, 9 infrared radiation, 10, 40; see also greenhouse effect inheritance of characters, 20, 2, 23-32; 26, 5-6 dominant and recessive, 20, 26-7, 30, 38, 41-2 Mendel's experiments, 20, 6-7, 30-1, 33, Plate 11 model of, 1, 9; 20, 23-30 more than one pair of contrasting, 20, 33-45 independent assortment, 20, 33-40 linkage and, 20, 40-4 one pair of contrasting, 20, 3-8 see also heritable character; meiosis; mitosis inherited character see heritable character; inheritance inhibition of enzymes see negative feedback initiator, 17-18*, 79, 80, 96 initiator codon, 24*, 38 inner core of Earth see under core inorganic phosphate (Pi), 22*, 11, 44, 48, 49, 51, 52, 53, 54, 55, 56, 57, 63; 24, 29 insecticides, 17-18, 5, 17, 47, 49, 95; 25, 34-5, 53-4, 59 insects, 19, 4, 5, 11; 25, 59; 28-29, 68, 70 adaptation, 19, 13 biological control of pests and, 25, 54-5 butterfly, 26, 13-14 chitin and, 22, 17 damaged by ionizing radiation, 31, larvae, 25, 44; 26, 12, 13, 19

KETONES

insects (continued) oxygen supply, 23, 8, 10, 12 population density, 25, 34-5 see also Drosophila; holly leaf miner; peppered moth; stick insertion (of a base), 26, 8, 17 instantaneous speed, 3*, 5 instrumental limitations in experiments, 4, 17 insulin, 19, 9; 22*, 20, 22; 23*, 27, 28, 31, 32, 26, 12, 18 biosynthesis of, 24, 38, 45-9 intelligence testing, 1, 6 intensity of an earthquake, 5-6*, 14, 20, 22, 37 intensity of radiation, 10*, 43 interactions, 30, 7, 10 of particles see fundamental interactions quantum behaves as particle in, 30, 12, 13, 17 intercept, 4*, 12, 13 interference see superposition interferon, 24, 46 interglacial deposits, 28-29*, 74 intermediates, metabolic, 22*, 14, 27, 64 see also metabolites intermediate vector bosons, 32*, 39, 40-1, 42, 43 intermolecular forces, 17-18*, 11, 12-13, 23, 86-7 internal body temperature, 23, 23-4 internal energy, 9*, 3, 4, 5, 6-7, 23-30, 35 heat and, 9, 3, 23-5 transfer, 9, 24, 25-7, 35 temperature and, 9, 23-5, 27-9 internal temperature of Earth see temperature International Commission on Radiological Protection, 31, 35 International Union of Pure and Applied Chemistry (IUPAC), 17-18, 3 interpolation, 4*, 11 interstellar dust, 28-29, 78 intestines, 23, 25 introns, 24*, 44, 45, 47 intrusive (plutonic) rocks, 5-6*, 8, 77, in Stratigraphic Column, 28-29, 32-3, 35, 37 see also igneous rocks invertebrates, 21, 31-2 genetic variability, 21, 13, 14 in vitro, 22*, 25 in vivo, 22*, 27, 44, 61 iodine, 13-14, 18, 19, 25, 42-3, 73, 74 in carbon compounds, 17-18, 9, 10 combination with tin, determining formula, 13-14, 10, 11-14 as molecular covalent substance, 13-14, 53, 54, 55, 56 physical properties, 17-18, 11-12, 13, 84 preparation of, 13-14, 54 iodine monochloride, 17-18, 13 ions, 11-12*, 5, 8-9, 11, 36, 69; 22, 14; 23, 22 diatomic, 13-14, 73 excreted, 23, 26

monatomic, 13-14, 49, 56, 57

polyatomic, 13-14, 49, 56, 57, 62 see also anions; cations ion microprobe, 28-29, 36 ion product of water, 15*, 25, 26, 27, ionic bonding, 13-14*, 59, 60, 65, 70 ionic compounds, solubility of, 17-18, 23 ionic interactions, 22*, 23, 29 ionic substances, 13-14*, 51, 52, 53, 70, 72, 76 and aqueous solutions, 13-14, 43-51, 56, 57 ionic theory, 15, 6-7 ionization energy, 11-12*, 33, 34-5, 37-40, 46; 13-14, 58, 65-6 first, 11-12, 62, 63-6 successive, 11-12, 37, 38 ionizing radiation, 31*, 34, 35, 36 and changes in DNA, 24, 41, 43; 26, 5, 6; 31, 34, 35 iron, 13-14, 5, 37-9 alloys in cytochromes, 22, 56 in Earth's core, 28-29, 49 in meteorites, 28-29, 43, 51 in Earth's core, 5-6, 72, 75-6, 80; 28-29, 42 in haemoglobin, 23, 19, 20 in meteorites, 28-29, 43-4, 45, 50-1 in oceans, 28-29, 59, 69 oxidation, 17-18, 70 oxides, 28-29, 48, 49, 52-3, 57, 60, 63-4, 69 in planets, 28-29, 39, 47-8, 49, 50 prospecting for, 5-6, 88 proteins containing, 22, 24, 56 reduction of oxide, 17-18, 71 in rocks, 27, 6, 7-8, 9, 10, 11, 15, 16; 28-29, 53, 59, 60, 63-4, 65, igneous, 27, 18, 22-3 sedimentary, 27, 37, 40, 41, 44, 45 weathering of, 27, 32, 33 see also ferromagnesian minerals iron meteorites, 5-6*, 75; 28-29*, 43, 45, 47 ironstone see banded ironstone formations iron sulphide in Earth's core, 28-29, 42, 49 in meteorites, 28-29, 44, 45 irruptions, 25, 36 Isacks, Brian, 7-8, 56, 81 island arcs, 7-8*, 10, 15, 69-70, 72, 73; 27, 24–5, 26–9, 52 islands and evolutionary theory, 26, 6-8, 13-14, 17 isocitrate dehydrogenase (ICDH), 22, 45, 58-9 isocitric acid, 22, 45 isolation, reproductive, 21, 23, 24, 25-7; 26, 8 isoleucine (Ileu), 22, 21; 24, 36 isomaltose, 22, 20 isomers/isomerism, 17-18, 37, 53 see also geometric isomers; optical isomers; stereoisomers; structural isomers isostasy/isostatic equilibrium, 7-8*, 19, 21, 26, 32-3, 76 and gravity anomalies, 7-8, 30-6 isostatic readjustment, 7-8, 21-2, 26; 28-29, 76, 79, 80

isotopes, 11-12*, 8, 10-11, 12, 16-17, 69; 17-18, 93; 28-29, 80; 31*, 18, 19, 25, 27, 36 of carbon, relative atomic mass of, 13-14, 16, 25 daughter, 28-29, 27, 28-9, 30, 31, 36 decay rates, 28-29, 50, 57 and dating of rocks, 28-29, 26-31, 35, 36-7 half-lives of, 13-14, 41; 28-29, 26-31 of neon, 13-14, 29 parent, 28-29, 27, 28, 30, 31 in replication experiment, 24, 19, in rocks, 27, 18, 19, 29 stable, 31, 18-19, 25, 27 in study of production ecology, 25, see also radioactive decay; radioactivity; unstable isotopes isotopic labelling, 22*, 41, 63; 25, 12

Japan Trench, 7-8, 36, 37 Jeans, James, 28-29, 40-1 Jeffreys, Harold, 7-8, 24; 28-29, 40-1 jellyfish (Cyanea), oxygen supply, 23, 7-8 joints (in rocks), 27*, 47, 54, Plates 3 and 4 joule, 9*, 11, 12, 13, 25, 33 Joule, James, 9, 8, 26 heat transfer experiment, 9, 25, 26-7,35Joyce, James, 32, 26 J/ψ particle, 32, 31-4, 36 Juan de Fuca Ridge, 7-8, 42, 43, 45 jumping genes, 20, 50 Jupiter, 28-29, 38-9, 41 moons of, 2, 42-3, 44 orbit of, 2, 36, 38, 40 Jurassic Period, 28-29, 24, Plate 31 fossils in, 28-29, 12 in Stratigraphic Column, 28-29, 20-1, 23

K

karyotype, 20*, 20, 21
Kelvin, Lord, 9, 23; 28–29, 26
kelvin scale, 9*, 23, 24, 25, 29
absolute zero, 9, 24, 28
Kepler, Johann, 1, 44; 28–29, 37
and planetary motion, 2, 5, 34–6, 39–40
first law, 2*, 35
second law, 2*, 36
third law, 2*, 36
third law, 2*, 39, 40, 42, 44
Kermadoc-Tonga Trench, 7–8, 13, 52
ketones, 17–18*, 39–40, 42, 70
chemical reduction of, 17–18, 73
formation from secondary
alcohols, 17–18, 72

Kettlewell, H. B. D.: experiments with moths, 19, 16-20 key mortality factors, 25*, 42, 55 kidneys active transport in, 22, 9 and elimination of wastes, 23, 23, 24, 26 glucose reabsorbed in, 23, 25 kilogram, 2*, 9 kilowatt-hours, 9, 12 kinetic energy, 9*, 2, 5, 16–19; 23, 14 of atoms, 9, 28–9 and chemical reactions, 16, 20-1, 33-4 conservation and non-conservation of, 9, 20-2 conversions to and from, 9, 2, 14, 15, 16, 18-19, 23 formula for, 9, 16-18 of photoelectrons, 10, 42-7 and ions, 11-12, 9, 27, 39-40, 41 kinetochore fibres, 20, 20, 49 kingdoms, 21*, 29, 32, 33; 26, 3, 15 Knoppe gall, 25, 59 koala bear, 25, 4 Krebs cycle see tricarboxylic acid cycle krypton, 11-12, 22; 13-14, 28, 31, 37-8, 58 in atmosphere, 28-29, 52, 57 energy-level diagrams, 11-12, 42, 44 first ionization energy, 11-12, 64 light, wavelength of, 2, 7, 8 photoelectron spectrum, 11-12, 41-2, 44, 59 Kuhn, Thomas, 7-8, 79-80 Kuril-Kamchatka Trench, 7-8, 13 k-value, 25*, 39 k-value analysis, 25*, 39, 40-4, 45-53,

L

lactate see lactic acid lactate dehydrogenase, 22*, 58 lactic acid (lactate), 17-18, 59; 22*, 58 synthesis of, 22, 58; 23, 26, 27 lactose, 17-18, 62 ladybird beetle (Rodolia cardinalis), 25, 54 lakes, 7-8, 68-9 Lamarck, Jean Baptiste, 19, 12, 15 Laminaria (seaweed), 25, 57 laminated sediments, 27, 38 lampshells, 28-29, Plate 23 land, emergence of life onto, 28-29, 58, 59, 61, 67, 69–70 land-bridge theory, 7-8, 18, 19, 20, 24 Landsat image, 28-29, Plate 32 lanthanides, 13-14*, 38, 39-41 discovery of, 13-14, 75 lanthanum, 13-14, 38, 39 Laplace, Marquis de, 28-29, 40 Laputians in Gulliver's Travels, 1, 9-10 Lapworth, Charles, 28-29, 23 Large Electron-Positron storage ring (LEP), 32, 8 large-scale objects see macroscopic objects larvae, 25*, 44; 26, 12 holly leaf miners, mortality of, 25,

45, 46, 47, 50, 51

midge, 25, 17 parasitic, 25, 35 latitude, 5-6, 48-53 Laurasia, 7-8, 25 lava, 5-6*, 8; 7-8, 64, 69, 71; 27, 19-20, 26, Plate 3; 28-29, 35, 55 pillow, 7-8, 63, 65, 68-9, 78; 28-29, 22 in Stratigraphic Column, calibrating, 28-29, 32, 33 lava flow, 5-6*, 8, Plates 11 and 12 law (scientific), 1, 8 lawrencium, 13-14, 39, 41 layering of planets, 28-29, 47-50, 57 L configuration, 17-18, 60-1, 93 Le Chatelier, Henri, 15, 17 Le Chatelier's principle, 15*, 16, 17, 18, 22, 37; 16, 29, 31 Le Pichon, Xavier, 7-8, 55, 56, 81 leaching of soil, 25, 27, 32 lead isotopes, 28-29, 30, 36, 37, 42 in rocks, 27, 6; 28-29, 21 Lederman, Leon, 32, 36 leeches, 25, 17 'left-handed' forms see chirality length, measurement and standards of, 2, 5, 6-8 lens, convex, 10, 30, 31, 32 LEP (Large Electron-Positron storage ring), 32, 8 lepton-quark symmetry, 32*, 30, 31-7 charm discovered, 32, 31-4 new lepton discovered, 32, 34-7 see also leptons; quarks leptons, 32*, 4, 12, 13-16, 42-3, 44 baryon number, 32, 21 interactions of, 32, 15-16 strangeness, 32, 22 symbols for, 32, 13 see also lepton-quark symmetry leucine (Leu), 17-18, 93; 22, 21; 24, 36, 37 Lewis, Gilbert, 13-14, 61; 17-18, 37 Lewis structures, 13-14*, 61, 62, 63, 64, 65, 67, 70; 17-18, 8, 9, 37, lichens, 19, 16 life, 19, 4-11; 26, 3, 15 cellular nature of, 19, 5-8, 11 chemical nature of, 19, 8-9, 11; 22, 14-15 diversity of, 19, 4-5 investigation of, 19, 9-10 origin of, 17-18, 91-4; 28-29, 62 - 71early atmosphere, 28-29, 62-3, 69 evolution of early life, 28-29, 63-4, 69 Mesozoic seas, 28-29, 68, 70 Palaeozoic, 28-29, 67-8, 70 Precambrian, 28-29, 64-6 Tertiary, 28-29, 68, 70 see also fossils processes of, 19, 10-11 see also animals; plants and under oceans; water life cycles, 22, 4; 25, 37, 45 life table, 25*, 38, 55 see also k-value analysis light, 9, 4, 5–7, 12 energy

conversion into, 22, 9 from see photosynthesis plane-polarized, 17-18, 57-9, 62-3, Plates 6-8 speed in vacuum, 2, 8; 31, 24, 27; 32, 4, 6, 7 waves, 10, 3, 25-41, 51, 53-4 electromagnetic, 10, 3, 39-41, speed of light, 10, 38-9 wavelength of, 2, 7 **light energy**, **9***, **4**, 5–7, 12 lightning, **17–18**, 91, 92 energy of, 9, 12 light stage of photosynthesis, 22*, 63 limestone, 5-6*, 8, Plate 8a; 27*, 40, 41, 45; 28-29, 4, 14, 20-1, 24 formation of, 28-29, 58, 59, 60, 61, 68 fossils in, 28-29, 18 joints in, 27, 47 limpets (Patella species), 25, 4, 57 linear accelerator, 32*, 8, 10 linear magnetic anomaly, 7-8*, 40 lines of force, 5-6, 43 line spectrum of an atom, 11-12*, 24, 26, 27-9, 30, 70-1 linkage group, 20*, 40-2, 43 link reaction, 22*, 44, 45, 46, 47, 49-50, 54 Linnaeus, Carolus (Carl von Linné), 21, 29-30; 26, 3 Linnean Society: paper by Darwin and Wallace, 19, 32 lipase, 17-18, 64; 22*, 16, 27, 32 liquefaction of air, 13-14, 75 liquids and chemical reactions, 16, 13, 14, internal energy of, 9, 23-5, 27-9, 30 and oxygenation see blood; water lithium, 13-14, 72; 28-29, 46 chemical bonding, 13-14, 58, 59, 65 lithium fluoride, 13-14, 59 lithium oxide, 13-14, 26, 72 lithosphere, 7-8*, 33, 34, 35, 58 litmus, 15, 4, 5-6 litter see detritus 'Little Ice Age', 28-29, 72 liver, 26, 9, 10, 12, 18 alcohol dehydrogenase in, 22, 31, 57 biosynthesis in, 22, 55 blood supply to, 23, 25 cells in, 22, Plate 4 glucose converted and stored in, 22, 43, 48; 23, 24, 26, 27, 38 living world see life lock and key model of enzyme action, **22***, 27, 32, 69 **locus**, gene, **20***, 24, 25; **26**, 5, 13, 16 lodestone, 5-6*, 40 logarithmic scale, 5-6*, 19 logarithm to the base ten, 15*, 27, 28; 25, 40 logical process, deduction as, 1, 7 London forces, 17-18*, 11, 12, 13, 23, London, Fritz, 17-18*, 11 long form of Periodic Table, 13-14, 30-3, 35, 39, 41, 76 longitude, lines of, 2, 15 long Periods in the Periodic Table,

13-14*, 30, 31-3

low-density (high-pressure) polymer, 17-18, 85 lower mantle, 5-6*, 66, 68, 80-81 low-grade metamorphism, 27, 51 low-speed layer, 5-6*, 67, 81; 7-8, 34, 76 Lullington Heath, 25, 61, Plates 11a and b lunar eclipse see Moon lunar month, 1, 22 lunar phases, 1*, 17, 22, 35, 41, 42, 47 lungs, 23, 8-9, 10, 11, 13, 21, 22, 24, 32, 33 lustre, 27*, 7 L-waves (Love waves), 5-6, 28, 90 Lyell, Sir Charles, 28-29, 23, 25-6 Lyman series, 11-12, 30-3, 35, 47 lysine (Lys), 22, 21, 23, 30, 45; 24, 36

M

McKenzie, Dan, 7-8, 52, 76, 77, 81 macromolecules, 17-18*, 74, 78 biological, 17-18, 88-90 synthetic, 17-18, 84-7, 95-6 macronutrients; necessary for life, 25, 21, 29 macroscopic objects motion of, Heisenberg's uncertainty principle applied to, 30, 32 and quantum mechanics, 30, 32-3 diffraction of, 30, 33-4, 35 macroscopic properties, 9, 28 magma, 5–6*, 7; 7–8, 63, 64, 66, 69; 27, 10, 11, 19–24, 29; 28–29, and metamorphism, 27, 52-3, 54 in Stratigraphic Column, calibrating, 28-29, 32 magnesium, 11-12, 5; 13-14, 50, 52 in alloy, 13-14, 69 chemical bonding, 13-14, 60, 65, 66, 69 electronic configuration, 11-12, 60 emission spectrum, 11-12, 56 first ionization energy, 11-12, 64 mass spectrum, 11-12, 10 in meteorites, 28-29, 44 in oceans, 28-29, 59-60, 61 photoelectron spectrum, 11-12, 52 Zeeman effect in, 11-12, 56 in rocks, 27, 6, 7-8, 11, 15, 16, 18, 22-3, 40; 28-29, 46, 49 transport and deposition of, 27, 32, 33, 41 see also ferromagnesian minerals magnesium chloride, 13-14, 42-3, 45, 48, 49-50, 51, 52, 66 in solution, 15, 11-12, 15-16, 18 magnesium hydroxide as precipitate, 15, 16 in solution, 15, 7, 9, 13-14, 15-18 as electrolyte, 15, 18, 19 magnesium nitrate, 13-14, 60 magnesium oxide, 13-14, 60 magnetic anomalies, 7-8*, 27, 40, 41-7, 52, 58 magnetic declination, 5-6*, 49, 52, 82 magnetic dipole, 5-6*, 47, 52, 55, 56,

magnetic dip poles, 5-6*, 52, 55

magnetic field, 5-6*, 43; 10, 39; 11-12, 53, 68 of bar magnets, 5-6, 41-6, 51, 70, 71,82 degeneracy and, 11-12, 55-8 of Earth, 5-6, 41, 47-53, 57-8, 69-72 changes in, 5-6, 52, 54-6 and paleomagnetism, 5-6, 82-7 reversal, 5-6, 56, 86-7, Plates 22 and 23 source of, 5-6, 69-72 strength of, 5-6, 49-51 electron spin and, 11-12, 53-4 magnetic inclination, 5-6*, 48, 49, 82, 83 magnetic interaction, 31, 19, 20 magnetic polarity reversals, 7-8, 44-5 time-scale, 7-8, 11 magnetic poles see geomagnetic poles; polar wandering; poles magnetic prospecting, 5-6*, 88 magnetic quantum number, m1, 11-12*, 55, 57, 58, 59 magnetic spin quantum number, m, 11-12*, 53-4, 55, 58 magnetism Earth, 5-6, 40-59 rock, 5-6, 82-8 temperature and, 5-6, 57 magnetite, 27, 37 magnetometer, 5-6*, 82-3, 88; 7-8, 27, 40-7 magnetron, 10, 40 magnitude of an earthquake, 5-6*, 19, 20, 21, 89 magnitude of a quantity, 3*, 6 Maiani, Luciano, 32, 31, 34 main group elements, 13-14*, 36 maintenance, 22*, 5 maize inheritance, 20, 3-6, 33-40 life cycle, 20, 3 malaria, 21, 16-19 malic acid, 22, 45 maltose, 22, 20 mammals, 19, 11, 13-14; 21, 31-2 blood supply, 23, 37 body temperature, 23, 24 damaged by ionizing radiation, 31, 34-5 heart, 23, 34 oxygen supply, 23, 8-9, 10, 12 time when appeared, 28-29, 11-12, 68; 32, 45 manganese nodules, 7-8, 63, 64 Maniola jurtina (meadow-brown butterfly), 26, 13-14 manipulating statistics, 4, 13 mantle, Earth's, 5–6*, 12, 60, 77; 28–29, 42, 49, 50, 51 composition of see peridotite and igneous processes, 27, 17, 18-19, 21-4, 29, 52-4 properties of, 5-6, 68, 81 structure of, 5-6, 66-8; 7-8, 33-4 mantle plumes, 7-8*, 78 map, geological, 28-29, 18-19 marble, 28-29, 20-1 marine see oceans marker horizon, 28-29*, 8, 13, 34 marl, 28-29, 20-1

Mars, 28-29, 38-9, 41, 47, 48, 80

orbit of, 1, 32-3, 45; 2, 31, 35-6, 38, 40 mass, 3*, 12, 13 acceleration and, 3, 12-13, 23 of α-particles, 11-12, 14 of atom, 11-12, 7-11, 17, 72-4 conservation of, 13-14, 15 of Earth, 3, 36-8 of electron, 11-12, 14, 66-9, 77; 30, 10, 14 and energy, 31, 24, 27 gravity and, 3, 18-22 molar, 13-14, 17; 16, 33-4, 35 molecular, relative, 17-18, 11 of Moon, 3, 38-9 of particles energy and, 32, 6 units of, 32, 7 rest, 31, 24, 26-7 standards of, 2, 9 weight and, 3, 20, 21, 23 see also kilogram; relative atomic mass and under Earth mass number, (A), 11-12, 11, 17, 18, 19; 31*, 17, 18, 27 mass spectrometer, 11-12*, 8, 9-10, 11, 37, 40; 17-18, 50 mass spectrum, 11-12*, 9, 10, 11, 24, 69 mathematical models, 1, 9 mathematical symbols, meaning of some, 2, 12 matrix, mitochondrial, 22, 46, 47, 56, 58, 61 matter descriptions of behaviour see quantum mechanics diffraction of, 30, 11, 12, 13, 14-17, 26-7, 32 macroscopic, 30, 33-4, 35 interaction of light with, see particles models of, 30, 9-12, 13, 14, 17 type of wave associated with, 30, 14-22 see also quantum; quantum mechanics Matthaei, Heinrich, 24, 36, 37 Matthews, Drummond, 7-8, 43, 44, 46, 52, 58, 81 maximum valencies, 13-14*, 27 Maxwell, James Clerk, 10, 3, 39 mean see average measurement of energy, 9, 7, 8, 9-13 transferred by constant force, 9, 9 - 10units, 9, 11-12, 13 in practical work, 4, 4, 17-20 standards primary, 2, 6, 9 secondary, 2, 6, 9 mechanical energy see gravitational energy; kinetic energy; strain energy mechanical equilibrium, 15, 12 mechanics, Newtonian, 3, 40 see also Newtonian mechanics medulla (of brain), 23*, 32, 33, 34, 36 Meinesz, Vening, 7-8, 34-5 meiosis, **20***, 8–10, 11, 12–21; **24**, 4, 7; **26**, 4–5, 15 chromosomes and gamete production, 20, 11-17

meiosis (continued) DNA and chromosomes, 20, 8-10 mitosis compared with, 20, 46-8 recombination during, 21, 19-21 see also inheritance of characters mélange, 7-8, 74 melanin, 22, 6 melt, crystallization from, 27, 5, 15, 16, 20-3, 25, 28, 29 melting, partial, of peridotite, 27, 21-4, 29, 52, 54 see also temperature membranes, 22, 16, 20, 38-9, Plates 4 and 5; 26, 4, 16 proteins, 22, 20 see also chloroplasts; mitochondria; ribosomes Mendel, Gregor, 19, 29; 24, 42; 26, 5, Mendelian genetics and evolution, 21, 3 inheritance experiments, 20, 6-7, 30-1, 33, Plate 11 Mendeléev, Dmitri, 1, 8; 13-14, 4, short Periodic Table, 13-14, 26-9, 33, 40, 41, 76 critique of, 13-14, 29-30 Mendocino Fracture Zone, 7-8, 41 menstrual cycle, 20, 20 Mercalli scale, 5-6*, 14, 20 Mercury, 28-29, 38-9, 41, 47 orbit of, 2, 31, 36, 38, 40 mercury, 11-12, 5, 72, 74 in rocks, 27, 6 vapour spectrum, 11-12, 25 Meselson, Matthew, 24, 19, 20, 50 Meselson and Stahl experiment, 24*, 19, 20, 50 mesons, 32*, 22, 26, 27, 32-4 mesophyll cells, 22, 63, Plate 7 Mesozoic Era, 28-29, 4, 15, 17 climate of, 28-29, 72, 78 fossils in, 28-29, 12, 66, 68 life in, 28-29, 68, 70 in Stratigraphic Column, 28-29, 20-1, 23 see also Cretaceous; Jurassic; Triassic messenger RNA (mRNA), 24*, 22, 42, 45; 26, 8, 17 codons, 24, 27, 28, 29, 31; 26, 9, 17, 18 genetic code and, 24, 35-7, 39 mutation and, 24, 40, 41 proteins and, 24, 23, 24-5, 27-31, 44-5, 46-7 translation and, 24, 31-2, 33, 34 metabolic pathways, 22*, 7, 14, 27, 43, 45 metabolism, 22*, 7, 14, 25, 43, 57, 60; 26, 9 experimental techniques, 22, 40-2 removing products of, 23, 21-4 carbon dioxide, 23, 21-2 heat transfer, 23, 23-4 water and nitrogen compounds, 23, 22-3 see also adenosine triphosphate; anabolism; biosynthesis; catabolism; enzymes metabolites, 22*, 14, 38 see also intermediates metallic bonding, 13-14*, 68, 69, 70

metals/metallic substances, 11-12, 25, 66; 13-14*, 25, 26-8, 30-1, 68, 69, 70, 74, 76 acceleration and, 3, 12-13, 23 α-particles experiment with, 11-12, 13-14, 18; 32, 2, 6, 24 atomic mass and number, 11-12, 24 atomic spectra, 11-12, 36 boundary with non-metals, 13-14, 69-70 chemical bonding, 13-14, 58, 59, 60, 65, 66, 68-9, 70 of Earth, 3, 36-8 electronic configuration, 11-12, 60-2 electron shells, 11-12, 44 electron spin, 11-12, 57 emission spectra, 11-12, 45, 50, 56 energy-level diagrams, 11-12, 45, gravity and, 3, 18-22 as ionic substances, 13-14, 46, 48, 50, 52, 57 conductivity, 13-14, 43-4 ionization energies, 11-12, 37-8, 39, 64 isotopes, 11-12, 17, 22 mass spectra, 11-12, 10 of Moon, 3, 38-9 photoelectron spectra, 11-12, 48 smelting, 13-14, 74 solution of oxides as bases, 15, 30-1 standards of, 2, 9 tolerance of grass to, 21, 9, 10 tungsten atoms, 11-12, 4, 5, 6 weight and, 3, 20, 21, 23 work functions of, 10, 46-7, 53 see also alkali metals metamorphic grade, 27*, 49, 51 metamorphism/metamorphic rocks, 5-6, 79; 7-8, 39, 71, 72; **27***, 5, 16, 46, 49-53; 28-29, 65 age of, 28-29, 31, 35 contact, 28-29, 32, 33 and meteorites, 28-29, 45, 51 minerals in, 27, 15-16 metaphase in meiosis, 20, 13, 14, 16, 21, 29, 37; 26, 15 compared with mitosis, 20, 46-7, 48 Metazoa, 28-29*, 39, 59, 64, 65, 70 meteoric water, 28-29*, 55 meteorites, 28-29*, 39, 41, 42-7, 50-1,80 ages of, 28-29, 36-7 chondrites, 28-29, 44, 45, 46, 47, 49, 51 chondrules in, 28-29, 44, 45, 51 iron, 5-6, 75; 28-29, 43, 45, 47 stony, 28-29, 44, 51 stony-iron, 28-29, 44, 45, 51 methanal see formaldehyde methanamine, 17-18, 21 methane, 13-14, 20, 56, 60, 62; 28-29, 57, 60, 62 bonding and molecular structure, 17-18, 7-8, 27 combustion of, 16, 2, 15, 18 North Sea gas, 17-18, 7 physical properties, 17-18, 10-11 in primordial atmosphere, 17-18, 91 - 2

methanoic acid see formic acid methanol bonding and molecular structure, physical properties, 17-18, 11, 13, 22-3, 24 reaction with acetic acid, 17-18, 81 methionine (Met), 24, 36, 37, 38 see also initiator codon methoxyethane, 17-18, 32, 70 1-methoxypropane, 17-18, 35 2-methoxypropane, 17-18, 35 methyl acetate, 17-18, 81, 94 methylamine bonding and molecular structure, 17-18, 9 physical properties, 17-18, 11, 13 reaction with acetic acid, 17-18, 81 methylated spirits, 17-18, 9 methyl group, 17-18*, 9 4-methylheptan-3-one, 17-18, 48 3-methylhexane, 17-18, 59 2-methylpropan-1-ol, 17-18, 34, 73 2-methylpropan-2-ol, 17-18, 34, 73 2-methylpropene, 17-18, 41-2 methyl radicals, 17-18, 96 metre, 2*, 6, 7, 8 metric system, 2, 6-8, 9, 11 micas in rocks, 27*, 6, 9, 10, 11, 15, 16, 32, 49, Plates 6 and 7 transport and deposition of, 27, 36 weathering of, 27, 33, 34 micrometer, 4, 5 micronutrients ('trace elements'): necessary for life, 25, 21 microfossils, 27, 40, 41; 28-29, 64-5 micro-organisms, primitive, 28-29, 59, 63-5, 69-70, 74-5 and source of atmospheric oxygen, 28-29, 54-5, 57, 58, 61 in soil, 25, 11 see also Clostridium tetani; Escherichia coli micro-plates, 7-8, 74 microprocessor, 17-18, 5 microwaves, 10, 40 Mid-Atlantic Ridge, 7-8, 13, 29, 38 central rift see axial rift crustal plates and, 7-8, 60 deep-sea drilling and, 7-8, 49 fracture zones and, 7-8, 51, 54, 58 midge larvae, 25, 17 Midgeley, Thomas, 17-18, 14 Milankovitch, M., 28-29, 78 Miller, Stanley, 17-18, 92-3; 28-29, 62, 69 milligal, 7-8*, 32 Millikan, Robert, 10, 48; 11-12, 66-7, 68-9 minerals, 27*, 5, 6-9 dating, 28-29, 27-31 investigating structure of, 32, 6 iron-bearing, 28-29, 52 and metamorphism, 27, 50, 54 in oceans, 28-29, 56, 58-60 residual, 27, 33 see also ferromagnesian minerals; silicate minerals mineral cycles, 25*, 21, 22, 29, 31 minor plates, 7-8, 55, 74, 78 Miocene Period, 28-29, 23 mirror image see chirality; optical

isomerism

MITCHELL'S THEORY NERVOUS SYSTEM

Mitchell's theory, 22, 56-7 mitochondria, 19, 18; 22*, 3, 38, 39, 40, 41, 44, 46, 47, 50, 55–7, 58, 61, Plates 4 and 5; 23, 26; 24, 22, 38; 25, 8; 26, 15 oxygen supply, 23, 4, 5, 6 mitosis, 20*, 17, 45, 46-9; 24, 4-5, 7, 14-15; 26, 4, 5, 15, 16; 31, 34 comparison with meiosis, 20, 46-8 mixtures, 13-14, 5 model, 1*, 9, 10, 44; 31, 11 of behaviour of light, 10, 3, 51 of Earth's shape, 1, 11-15, 43 of Earth, Sun and Moon, 1, 23-41, 43 of electromagnetic radiation, 30, 6-9, 13, 14 particle model, 30, 7-9, 14 wave model, 30, 6-7 of evolution by natural selection, 19, 30-6, 37 of hydrogen atom, 31, 4, 11-14 mathematical, 1, 9 of matter, 30, 9-12, 13, 17 de Broglie's wave model, 30, 10-12, 13, 14 particle model, 30, 10, 13, 14 molecular, 17-18, 25-7, 43, 60-1 of typical nucleus, 31, 21-2 see also nuclear model and waves 'Mohole' project, 7-8, 47 Mohorovičić discontinuity (Moho), 5-6*, 78-9, 81; 7-8, 47, 66, 79 molar mass (M), 13-14*, 17; 16, 33-4, 35 moles, 13-14*, 16, 17, 18-19, 25 per litre, concentration expressed as, 15, 11, 12 molecular biology, 26, 8-9, 14 molecular covalent substances, 13-14*, 53-5, 57, 60-1, 73 molecular formulae, 13-14*, 18, 19; 17-18*, 7, 8, 9, 47 molecular interpretation of effect of concentration and temperature on chemical reactions, 16, 20-1 molecular mass, relative, 17-18, 11 molecular models, 17-18, 25-7, 43, 60-1 molecular speed, 16, 20, 21 molecules, 9, 27; 13-14*, 9 diatomic, 13-14, 19; 16, 8-12, 14 monatomic, 13-14, 56, 57 polyatomic, 13-14, 49, 56, 57, 62 see also giant molecules; macromolecules Molina, Mario, 17-18, 15 molluscs, 25, 4, 17, 57 momentum, 3*, 15, 16-17; 30, 24 components of, 30, 24, 25, 26-9, 31, 32 conservation of, 9, 20-2, 36 of photons, 10, 42, 48-50; 30, 8-9, 13, 14 monatomic ions, 13-14, 49, 56, 57 monitors, 23*, 28, 31, 34; 26, 11, 18 monochromatic radiation, 11-12, 39-40 monocytes, 23, Plate 10 monolayer experiment, 11-12, 6-7, 11 monomers, 17-18*, 78, 79-80, 89; 22, 17, 20; 24, 10, 24

monosaccharides, 22*, 7, 15, 17, 43; 26, 11, 18 monosodium glutamate, 17-18, 62 month, lunar, 1, 22 Moon, 7-8, 7, 17 age of rocks on, 28-29, 36-7 and Earth: force of attraction between, 3, 21-2 apparent size of, 1, 17, 22 eclipse of, 1, 35, 37-8, 42, 43; 2, 20-1, 44-6 formation of, 28-29, 42 mass and density of, 3, 38-9 measuring distance to, 2, 22-6, 29 eclipse of, 2, 20-1, 44-6 radius of, 2, 20-2, 29 motion of, 3, 32-6 observation of, 1, 11, 12, 14, 17, 22 orbit of, 1, 34-8, 41, 43 phases of, 1, 17, 22, 35, 41, 42, 47 spin, 1, 38-9 moraine, 27, Plate 14 Morgan, W. Jason, 7-8, 52, 54, 55, 59, 81 Morley, L. W., 7-8, 44, 46, 81 morphology, 19*, 14, 32 mortality factors, 25*, 37, 55 key, 25, 42, 55 and k-value analysis, 25, 39-44, 45-53 regulating, 25, 42 mortality rate, 25*, 34-5, 36, 37, 55 density-dependent, 25, 36, 42, 45 density-independent, 25, 36-7, 42 total generation pre-reproductive (k_{total}), 25, 40, 41, 55 mosquitoes, 21, 18, 25 moth see peppered moth motion, 1, 23-4 circular, 1, 23, 24-6, 40, 41 and Heisenberg's uncertainty principle macroscopic objects, 30, 31 quanta, 30, 26-9, 31 laws of, see Newton see also orbits motor nerves, 23*, 34 mountain belt, 7-8*, 11, 12, 15, 21, 70 mountains chains, roots of, 27, 51, 52 volcanic islands as, 27, 20 mouse, house (Mus musculus), 25, 4; 26, 8 mouth, 26, 10 mRNA see messenger RNA μ lepton, 32, 13-15, 16, 31, 41, 43 mud and mudrock, 27, 51, 54 mudstone (mudrock), 5-6*, 8 multicellular organisms, 19*, 6, 11 evolution of, 28-29, 39, 64-5 oxygen supply in large, 23, 8-10 small, 23, 6-8 multiple bonds, 16, 9 'multiple-slit' see diffraction grating muon see µ lepton Murchison, Robert, 28-29, 22-3 muscles, 19, 5; 23, 27 anaerobic respiration in, 22, 57-8 and breathing, 23, 10 see also heart glucose conversion in, 23, 24, 26 'muscular' energy, 9, 3; see also

muscular work muscular work, 22*, 9 mussels, 25, 16, 17, 57 mutant, 19*, 30 mutation, 19*, 30, 31-2, 37; 20, 31; 21, 4-5, 9, 10; 22, 23; 24*, 4, 40, 41, 43, 50; 26, 5, 6, 13, 16, 17 neutral, 21, 15-16 see also dominant allele and character; evolution by natural selection; recessive allele and character mutation rates, 21*, 14, 15 myoglobin, 22*, 24, Plate 1 myxomatosis, 25, 60-1, 62

N

N (newton), 3, 14, 21 NAD (nicotinamide adenine dinucleotide), 22*, 31, 46, 47, 49-53, 54, 55-6, 57-9 NADP (nicotinamide adenine dinucleotide phosphate), 22*, 31, 63-4 naked bottoms, 32*, 37 naked charm, 32*, 34 naming organisms, 21, 30-1 natality rate, 25*, 34-5, 36, 37, 55 density-dependent, 25, 36, 42 Natta, Giulio, 17-18, 80, 85, 96 natural classification, 21*, 32 natural gas, 17-18, 7, 19 natural selection, theory, 19*, 12, 32 see also balanced polymorphism; evolution nautilus, 28-29, Plate 25 Nazca crustal plate, 7-8, 55, 60 nebula, 28-29*, 37 nebular theory of origin of Solar System, 28-29*, 37, 40, 41, 48 negative charge, 9, 30-1, 33 of atoms, 11-12, 15, 19 atomic spectra and, 11-12, 28, 36 negative feedback, 22*, 58; 23*, 29, 31, 33, 37; 26, 11, 18 nematodes, 19, 4 and food chains and food webs, 25, 11 neon, 11-12, 5, 7, 9-10; 13-14, 25 in atmosphere, 28-29, 52 atomic mass and number, 11-12, 24, 72 chemical inertness, 13-14, 58, 59 electron shells, 11-12, 42 energy-level diagram, 11-12, 43 isotopes of, 11-12, 11, 12, 16-17 mass spectrum, 11-12, 69 and Periodic Tables, 13-14, 26-8, 29, 31-2, 35-8 photoelectron spectrum, 11-12, 41-2, 59 Neptune, 28-29, 38-9, 41 orbit of, 1, 45; 2, 34, 40 nerves, active transport in, 22, 9 nervous system, 26, 11 and control of heartbeat, 23, 33-5,

nervous system (continued) control mechanisms and, 23, 33, 34-5, 37 glucose needed for, 23, 26 net primary production (NPP), 25*, 8, 9, 10, 11, 14, 18 neuron, 23*, 34 neutral mutations, 21, 15-16, 22 neutral solution, 15*, 5, 27 'neutralists', 21, 16 neutralization, 15*, 6, 8-9, 10, 32 reaction, 15, 27 neutrino, 31, 30, 31, 36; 32*, 13, 14-16, 31, 35, 43, 44 rest mass of, 32, 13-14 neutrons, 11-12*, 17, 18, 23; 31, 3-4, 17-18, 19, 27 decay of, 32, 29 and nuclear fission, 31, 38 quarks in, 32, 25, 27, 28, 29, 42, 43 and radioactive β-decay, 31, 30, 36 released by nuclear fission, 31, 37, 38, 40, 41 stability, 32, 18, 28 see also atomic nucleus New Hebrides Trench, 7-8, 52 new species see speciation Newfoundland: proposed terranes, 7-8, 74 Newton, Isaac, 1, 44; 3*, 4, 8, 12, 40; 28-29, 37 Blake's portrayal of, 1, 9-10 his Principia, 3, 4, 40 first law of motion, 3*, 9, 10 second law of motion, 3*, 14, 15, 20; 9, 17 third law of motion, 3*, 23 law of gravitation, 2, 36; 3*, 35, 36, 37; 9, 32; 31, 20; 32, 16 theory of mechanics see Newtonian mechanics Treatise on Opticks, 10, 3 newton, (N), 3*, 14, 21 Newtonian mechanics, 3*, 40; 30, 4, 24, 31, 34, 35 compared with quantum mechanics, 30, 4, 23, 31, 34, 35 niacin, 22, 31-2 niches, 25*, 57-8, 59, 62; 26, 8, 14, 17 nickel in Earth's core, 5-6, 75, 76; 28-29, 42, 47 in rocks, 27, 6; 28-29, 44, 46 nickel-iron alloys in Earth's core, 28-29, 49 in meteorites, 28-29, 43, 51 nicotinamide adenine dinucleotide see NAD nicotinamide adenine dinucleotide phosphate see NADP night see day and night Nirenberg, Marshall, 24, 36, 37 Nishijima, Kazuhiko, 32, 22 nitrates, 13-14, 49 active transport, 22, 9-10 and nitrogen cycle, 25, 25-7, 29, 31 as nutrients, 22, 14, 39, 64 nitric acid, 15, 6, 7, 8, 9 dissociated equilibrium in, 15, 23 in rain, 15, 31, 33 nitric oxide as pollutant, 15, 31-3 nitrification, 25*, 26, 27, 31 nitrites, 25, 26, 27

nitrogen, 11-12, 5, 20, 64; 13-14, 21, 74: 17-18, 10 in atmosphere, 28-29, 52, 55-6, 57, 58, 60 chemical bonding in molecules, 13-14, 60, 62 compounds eliminated, 23, 22-3, 24 excessive, 26, 14 fixing/fixation, 16, 2, 30-2; 19, 9; 22, 26; 25, 28, 29, 32 in meteorites, 28-29, 80 as molecular covalent substance, 13-14, 56 in organic compounds, 17-18, 8-9 in rocks, 27, 6 sources of, in living organisms, 22, 8-9, 14, 64, 67 nitrogenase, 22*, 26 nitrogen cycle, 25*, 25, 26-9, 31-2 nitrogen fixation, 25*, 28, 29, 32; see also nitrogen nitrogen trichloride, 13-14, 56, 60, 76 N-methylacetamide, 17-18, 81 noble gases, 11-12, 41; 13-14*, 25, 58-9, 75 absorption spectra, 11-12, 38, 48-9 in atmosphere, 28-29, 52, 55, 56, 57, 60 and chemical bonding, 13-14, 58-9, 61, 62, 63, 65, 70 discovery of, 13-14, 75 electron shells, 11-12, 42 electronic configuration of, 11-12, 46, 60; 13–14, 58, 59, 73, 76 energy-level diagrams, 11-12, 42-4 isotopes, 28-29, 30, 31 mass spectra, 11-12, 69 orbitals, 11-12, 59-60 photoelectron spectra, 11-12, 41-2, 44, 51, 52, 59 stability of, 13-14, 58 nonane, 17-18, 19 nonan-2-one, 17-18, 48 non-bonding electron pairs, 17-18*, 8 non-coding DNA, 24*, 45, 47 non-dipole component of Earth's magnetic field, 5-6*, 51, 52, 53, 54, 56, 58 non-electrolytes, 13-14*, 46 non-ionizing radiation and changes in DNA, 24, 41, 43 non-metals, 13-14*, 30-1, 69, 70, 76 boundary with metallic elements, 13-14, 69-70 chemical bonding, 13-14, 69, 70 solution of oxides as acids, 15, 30 non-overlapping (genetic) code, 24*, 38 non-polar solvents, 13-14*, 68; 17-18, 23 non-reproductive cells see somatic cells non-resistant phenotypes, 19, 26 non-stick pans, 17-18, 79 non-uniform magnetic field, 11-12, 53, 54 normal, 5-6*, 33 normal faults, 27*, 48 normal oxides, 13-14*, 26 North America; races of American

song sparrow, 21, 25

Northern Hemisphere, 1, 16, 30,

35-6, 42

seasons in, 1, 16, 31, 32 north pole of a magnet, 5-6*, 44 North Sea gas, 17-18, 7 Norway spruce (Picea abies), 25, 59 November Revolution, 32, 31-4 NPP see net primary production N-terminal amino acid, 24*, 28, 38 N-terminal amino acid residue, 22*, 21, 22; 24, 28, 29, 38 nuclear binding energy graph, 31*, 23, 25, 29, 37 nuclear bombs, 31, 33, 38, 39 nuclear chain reactions, 31*, 38, 39, 40 nuclear decay chain, 31*, 32, 33 nuclear decay channel, 31*, 32, 37, 38 nuclear energy, 9*, 5, 6, 7; 31, 37, 39-41 levels, 31, 21-2 see also nuclear power nuclear envelope of cell, 20, 13, 14, 15, 16, 19, 24, 29, 34, 46, 47, 48; 26, 16 nuclear explosions, detecting and monitoring, 5-6, 89-90 and seismology, 7–8, 34 nuclear fission, 1, 5; 11–12*, 22, 23; 31*, 37, 38, 41 induced, 31, 38 in nuclear power stations, 31, 39-40 spontaneous, 31, 32, 37 nuclear fusion, 11-12*, 22, 23, 71; 31*, 37, 39, 41 nuclear (Rutherford) model of atomic structure, 11-12, 12-14, 15, 16 - 18α-particle experiment, 11-12, 13-18; 32, 24 nuclear power stations and reactors, 31, 33, 35, 39-40, 42 nuclear reaction, 11-12*, 18, 19-23; 13-14, 15, 75 nuclear transfer experiments, 24*, 15, 16, 50 nucleic acids, 17-18*, 89; 19, 8, 11; 22, 7; 24, 5, 9, 17, 24, 35, 40, production of, 28-29, 62, 69 see also DNA; polynucleotides; RNA nucleolus, 24, 32; 26, 4 nucleotides, 17-18*, 89, 90; 22, 7; 24*, 10, 11, 17, 21 nucleus (atomic) 11-12*, 15, 16, 18; see also atomic nucleus; see also nuclear fission; nuclear fusion; radioactive decay of nuclei nucleus (cell) see cell nucleus nylon, 17-18, 4, 74, 78, 82, 86, 87, 91, 95, 96-7, Plates 3 and 10 nylon salt, 17-18, 96

0

oaks, 25, 59 obduction, 7–8*, 66, 71 observation, 4, 4 oceans/oceanic, 7–8, 10–11; 25, 10, 12, 21, 22–5, 31 biogenic precipitation from, 28–29, 63

oceans (continued)
buffering by, 25, 23, 24, 25, 31
composition of, 28-29, 59, 60, 61
/continental boundaries of, 7-8, 11
12, 15 continent destructive plate margin,
7–8 , 69–71, 72, 73
see also island arc
crust, 5-6*, 78, 79; 7-8, 5, 8-13, 19
33, 38; 28–29 , 47, 50
gravity anomalies, 7–8, 34–6
magnetic anomalies, 7–8, 40–7
plate margins, 7–8 , 63, 64, 70, 71–2
plate tectonics, 7–8, 52–5
spreading, 7–8, 38–40, 44–7,
49–50
curved surface of, 1, 12-13
deep circulation in, 28-29, 77
deposition in, 28-29, 63, 74-5, 79
deposition in, 28–29 , 63, 74–5, 79 depths, 7–8 , 8–9, 19, 56, 58
continental fit and, 7-8, 27-9
heat-flow measurement, 7-8, 36-7,
58
/ocean destructive plate margin,
7-8, 69-70, 72, 73
see also island arc
life in, 19, 5, 13–14; 28–29, 54–5,
57, 58, 61, 66, 74–5
and source of atmospheric
oxygen, 28–29, 54–5, 57, 58,
61
Mesozoic seas, 28–29 , 68, 70 minerals in, 28–29 , 56, 58–60
origin of, 28–29, 59, 58–60
oxygen in, 28–29, 59, 64, 66
ridges, 7–8*, 10, 11, 12, 15, 16, 42,
43, 45, 51, 55
plate margins, 7-8, 63, 64, 66, 73
77, 78
plate tectonics, 7-8, 29, 33, 38,
42
symmetry of, 7–8, 11, 12
see also Iceland; Mid-Atlantic;
Pacific sea-level changes, 28–29, 75–7, 79
surface heights, 7–8, 77
temperature of surface waters,
28–29 , 75
Tethys in Holmes' theory, 7–8, 25
trenches, 7-8*, 10, 11, 13, 15, 25,
51, 69; 27, 25
and gravity anomalies, 7-8, 34-6
see also Atlantic; Pacific; shores
octane, 17–18, 19
combustion of, 16, 15, 16
octan-1-ol, 17-18, 21
oesophagus, 26, 10
oil-drop experiment, 11–12, 66–8
oil pollution, 26, 14
Old Winchester Hill, 25, 61, Plates 12a and b
Oligocene Period, 28–29, 23
Oliver, Jack, 7–8, 56, 81
olivine
in meteorites 28–29, 44, 51
in planets, 28–29, 49
in rocks, 27*, 8, 9, 10, 11, 15, 16,
18, 20, 22, 23, 29
weathering, 27, 32, 33, 44
oncogenes, 31, 34
one-dimensional motion, 30*, 24
Onnes, Kamerlingh, 30, 34
pocytes, 20, 11, 20

```
oozes, 27*, 40
    calcareous, 7-8, 64
 Oparin, Alexander, 17-18, 91, 92
 operating theatres, 17-18, 4, 5
 ophiolite sequence, 7-8*, 66, 71
 optical activity, 17-18*, 59
   origin of, 17-18, 92-3
 optical isomers/isomerism, 17-18*,
        52, 53-6, 62-5
    and origin of life, 17-18, 93
 orbital, atomic, 11-12*, 15, 56, 57,
        59-60; 31, 15
 orbital acceleration, 3*, 32, 33-4
 orbital circular motion, 1*, 23, 24-5
 orbits
   circular, 1, 23, 24-6
   of Earth, 1, 28-9, 30, 31, 32-3,
        35-7, 41; 2, 30-1, 32, 34-6;
        28-29, 70
   of Moon, 1, 34-8, 41, 43
   of planets, 1, 32-3, 45; 2, 30-1, 32,
        34-6
   period of, 2, 36-40
   radius of, 2, 30-2, 34, 36-40
orchid (Ophrys insectifera), 19, 5
order (biology), 21*, 29, 32, 33; 26, 3,
       15
order of diffraction, 10, 34, 36
order of magnitude, 2*, 11, 12
ordering geological events see time
Ordovician Period
  fossils in, 28-29, 12
  ice age in, 28-29, 72
  in Stratigraphic Column, 28-29,
       20-1, 23
organelles, 19*, 6, 10, 11; 22, 40-1;
       26, 3, 15
  see also chloroplasts; eukaryote;
       mitochondria; nuclei;
       prokaryote; ribosomes
organic chemistry, 17-18*, 6; 19, 8-9
  importance of, 17-18, 3-6
  see also carbon compounds
organism see life
organochlorine insecticides, 17-18,
       47
organs, 19*, 5; 26, 3, 15
Orlon, 17-18, 87
outcrop, 28-29*, 18
outer core of Earth, 5-6*, 75, 81;
       28-29, 42, 49
ovalbumin, 24, 45
ovule, 20*, 8, 28
  see also eggs
ovum, 20*, 8
  production of, 20, 11, 20-1
  see also eggs, gametes
owls in Wytham Wood, 25, 36-43
oxaloacetic acid, 22*, 45, 50
oxidation, 17-18*, 70, 71-2; 23, 4, 26
  of organic fuels, 22, 3, 10, 41
     see also catabolism; oxygen
       supply
oxidative phosphorylation, 22*, 52, 53,
       54, 55, 56-7
  see also Mitchell's theory;
       mitochondria
oxides, 13-14, 14, 15, 26, 27, 30, 33,
       37, 40; 28-29, 52-3, 55-6, 57,
       58
  in planets, 28-29, 48, 49
  of sulphur and nitrogen; emission
       into atmosphere, 25, 30
```

ooliths, 27, 41

```
oxygen, 11-12, 5, 64; 13-14, 5, 18,
        20-1, 74; 25, 6-7, 13, 21; 26,
        15
   in atmosphere, 28-29, 57, 60, 62
   early, 28-29, 63-4, 65, 66, 67-8, 69
   levels, evidence for, 28-29, 52-3,
       60 - 1
   source of, 28-29, 54-5, 58, 61
   binding to haem, 22, 25
   in carbon compounds, 17-18, 8-9,
        10, 39-40
   chemical bonding, 13-14, 60-3, 67
  cycle, 25, 21
   in electron transport chain, 22, 25
  indicators, 28-29, 53
  as initiator of polymerization,
       17-18, 79, 96
  isotopic labelling, 22, 63
  measurement of concentration, 22,
       42
  in meteorites, 28-29, 80
  as molecular covalent substance,
       13-14, 56
  molecules of, 13-14, 9
  in oceans, 28-29, 59, 64, 66
  production of, 13-14, 50
  in rocks, 27, 6, 11
     and weathering, 27, 32
  supply in organisms, 23, 4-10
     diffusion of, 23, 4-6, 7, 8, 9, 10,
       24, 35
     transport in blood system, 23,
       11-12, 32-3, 37
     in large multi-cellular, 23, 8-10
     in small multi-cellular, 23, 6-8
  toxic to early life, 28-29, 63
  water formed from, 13-14, 20, 21
  see also aerobic respiration;
       electron transport chain;
       mitochondria; oxidation
oxygen debt, 22*, 58
oxygen electrode, 22*, 42
ozone hole, 17-18, 16, Plate 5
ozone layer, 17-18*, 15, 16, 17, Plate
       5; 28-29*, 54, 55
 P
```

Pacific Ocean borders of mountains, 7-8, 11, 12 volcanism and seismicity, 7-8, 14, 25, 81 crustal plate, 7-8, 55, 61, 70, 73 destructive plate margins, 7-8, 70 gravity anomalies, 7-8, 34-6 magnetic anomalies, 7-8, 41-2 Moon's birth from, 7-8, 17 ridges, 7-8, 29, 42, 43, 45 sea surface variation, 7-8, 77 spreading rate, 7-8, 46-7, 52 transform faults, 7-8, 52 paints, 17-18, 4 paired bases, 24, 11-12, 13, 17, 21 and genetic code, 24, 35-7 and protein synthesis, 24, 25, 31, 32 pairing of electrons, 11-12*, 55; 13-14, 59, 61 pairing of homologous chromosomes, 20, 13-14, 18-20; 26, 16

Palaeocene Period, 28-29, 23 palaeoclimatic see climates, past palaeoecology, 28-29*, 11, 13 palaeomagnetic see magnetic anomalies palaeomagnetic poles, 5-6*, 55, 83-7 palaeomagnetism, 5-6*, 54-6, 58, 82-3 palaeontology, 19*, 12 see also fossils Palaeozoic Era, 28-29, 4, 15, 22, 23, 57-8, 67-8, 70 dating, 28-29, 36 fossils in, 28-29, 12, 64, 66-8 life in, 28-29, 67-8, 70 in Stratigraphic Column, 28-29, 20-1, 23see also Cambrian; Ordovician; Silurian; Devonian; Carboniferous; Permian palladium, **13–14**, 38–9 palmitic acid, **22***, 15, 16, 61 pancake model of Earth, 1, 11-12 pancreas, 23*, 32; 26, 10, 11, 18 pancreatic juice, 26, 10 paranormal phenomena, 1, 6 parallax errors, 4, 17 parallel plates and standing wavefunctions, 30, 19-22, 23; 31, 5-8 parasites and diseases, 19, 5, 6 used for biological control of pests, 25, 53, 54 see also viruses parasitic wasps biological control of pests and, 25, mortality of holly leaf miners and, 25, 45, 46, 50, 51 parasitoids, 25*, 34, 35, 55 parasympathetic nervous system, 23*, 34, 35, 37; 26, 11 parental generation (P), 20*, 4, 23, 25, 26, 33, 35, 41, 42 parent-daughter ratio, 28-29, 27, 28-9 parent isotope, 28-29*, 27, 28, 30, 31 parent planets, 28-29, 44, 51 Parker, R. L., 7-8, 52, 81 partial melting (of mantle peridotite), 27*, 21, 22-4, 29, 52-3, 54 particles accelerators, 30, 5, 11 light as, 10, 3, 42-54 Compton effect, 10, 3, 48-50, 51 photoelectric effect, 10, 3, 42-8, 50, 53 mass of, 32, 6, 7 meaning in high-energy physics, 32, 3 models of electromagnetic radiation, 30, 7-9, 14 of matter, 30, 9-12, 13, 14, 17 quanta behaving as, 30, 12, 13, 17 see also collisions; fundamental particles; quantum; quantum mechanics; wavefunctions particle accelerators see accelerators particle-in-a-box model, 31, 8-10, 11-14, 15, 21-2, 27

Parus major (great tit) populations, 25, 34, 35-6 Paschen series, 11-12, 32, 47 passive continental margin, 7-8*, 60 Pasteur, Louis, 28-29, 64 Pauli, Wolfgang, 32, 13 Pauling, Linus, 13-14, 66 peas, garden: inheritance of characters, 20, 6-7, 23, 24, 27, 30-1; 24, 42-3; 26, 5 peat, 25, 10, 15 pendulum, 1, 20, 32 periods of, 1, 18, 19-21, 42 swing of, 1, 20-1, 24, 26-8 penguins, adaptation by, 19, 13-14 penta-1,3-diene, 17-18, 50 pentan-1-amine, 17-18, 21 pentane, 17-18, 19 pentan-1-ol, 17-18, 20 pentan-2-one, 17-18, 40, 41 pentan-3-one, 17-18, 40, 41 peppered moth (Biston betularia), 21, 3; 24, 9 and evolution, 21, 4-6, 10, 22 experiments with, 19, 16-20, 27-9, 30 mutation of, 19, 31 pepsin, 22*, 30; 26, 11 peptide, 22, 11; 26, 11 peptide bond, 17–18*, 69; 22, 21–2, 24; 24, 27, 29, 33; 26, 11 perch, adaptation by, 19, 13-14 peridotite, 5-6, 8, 60, 66, 67-8, 75, 81, Plate 13; 7-8, 34; 27*, 10, 17, 21; 28-29, 4, 42, 47-50 composition of, 27, 9, 14, 15, 18 formation of, 27, 20-1, 22, 24, 29 in meteorites, 28-29, 44, 45 and plate margins, 7-8, 63, 64, 66, 78 see also partial melting Period (chemistry), 13-14*, 27, 75-6 Periods (geological), 28-29*, 4, 25 names of, 28-29, 22-3 see also Cambrian; Ordovician; Silurian; Devonian; Carboniferous; Permian; Triassic; Jurassic; Cretaceous; Tertiary; Quaternary period (physics), 1*, 18 orbital, 2, 36-40, 42-4 of pendulum, 1, 18, 19-21, 42 periodic disturbances, 5-6, 25 periodicity, 1, 18-22, 24 Periodic Law, 1, 8; 13-14*, 27 periodic process, 1*, 18, 22 Periodic Table, 13–14*, 4, 25–6, 27, 28-42, 75-6 and electronegativity, 13-14, 65-8, 70-1, 72, 73 and electronic configuration, 13-14, 58, 59, 62, 63, 70 long form of, 13-14, 30-3, 35, 39, 41, 76 Mendeléev's short, 13-14, 26-9, 33, 40, 41, 76 critique of, 13-14, 29-30 relative atomic masses, problem raised by, 13-14, 29 period of a wave, 10*, 13, 16, 23 periwinkle, 28-29, Plate 21 Perl, Martin, 32, 34 Permethrin, 17-18, 47, 49 Permian Period fossils in, 28-29, 12

ice age in, 28-29, 72 in Stratigraphic Column, 28-29, 20-1, 22, 23 Perognathus species (seed-eating rodent), 25, 58 peroxides, 17-18, 79-80, 96 Perspex (Plexiglass), 17-18, 103 pesticides see insecticides biological control of, 25, 34-5, 53, 54, 55, 60-1 chemical control of (insecticides), **17–18**, 47–51; **25**, 34–5, 53–4, PET see polyethylene terephthalate petroleum, 17-18, 4, 19 pH in blood, 15, 29-30 in human digestive system, 26, 9, 10, 11, 18 of rain, 15, 30 see also pH optimum; pH scale pharmaceuticals, 17-18, 5, 63, 95 phase of a substance, 13-14*, 19 phase (waves), 10*, 20 phase changes (phase transitions), **5–6**, 66; **9**, 27–30, **16***, 5, 6, 16 phenol, 17-18, 41 phenotype, 19*, 19, 20; 21, 4–6; 22, 6, 23; 24, 4–5, 9; 26, 5, 6, 17 evolved see evolution fecundity and viability, 19, 23-4 fitness, 19, 25-7, 29-30 genes and, 24, 40, 43 new (mutated), 19, 30, 31-6, 37 phenotypic characters see heritable character; inheritance phenylalanine (Phe), 17-18, 60, 62; 22, 21, 45; 24, 27, 36 phenylethene see styrene phenyl group, 17-18*, 40, 41 phenylthiocarbonate (PTC), ability to taste, 21, 11 pheromones, 17-18*, 47, 48, 49-51, 52 and pest control, 25, 53 phoenix, 24, 17 pH optimum of enzymes, 22*, 29, 30, 36; 26, 18 phosphate groups, 17-18, 89; 22, 11, 16 phosphates, 13-14, 57; 22, 14, 64 in DNA, 24, 10, 11, 12 in RNA, 24, 24 see also inorganic phosphate phospholipids, 22*, 16, 25, 64 phosphorus, 11-12, 22, 61, 64; 13-14, 27-8, 31-2, 36-8, 65; 22, 16; 28-29, 62 cycle, 25, 29, 32 phosphorylation, 22, 54 oxidative, 22, 52, 53, 54, 55, 56-7 substrate level, 22, 49, 53, 54 photochemical dissociation of water, 28-29, 55, 57, 60 photochemical reactions and origin of life, 17-18, 91-2 photochemistry, 10, 49 photoelectric effect, 10*, 3, 42, 43-8, 50, 53, 11-12, 39; 30*, 7, 8, 13, Einstein's photoelectric equation, 10, 45-8, 50 wave model, failure of, 10, 44 photoelectrons, 10*, 42, 43-8, 53

particle physics, 31, 42; 32*, 4

see also fundamental particles

photoelectron spectroscopy and spectra, 11–12*, 39, 40–2, 46, 48, 52, 55, 59, 60 photoionization, 11-12, 39 photomultiplier, 10, 54 photon, 10*, 42, 49, 50, 51-2, 53, 54; 11–12, 36; 13–14, 61; 30*, 7; 31, 3, 7, 8, 14, 31–2, 36; 32*, 39, 43, 44 absorption see photoelectric effect energy of, 10, 45; 11-12, 39-40, 30, 7, 8, 13 momentum of, 10, 48; 30, 8-9, 13, 14 scattering see Compton effect see also electromagnetic radiation photophosphorylation, 22*, 63, 65 photosynthesis, 9, 5; 10, 4; 22*, 8, 12, 38, 39, 62-3; 23, 4; 25, 6-11, 15, 16, 22-25; **26**, 12, 15; 28-29, 63, 64, 66 ADP produced in, 22, 63, 64 in aquatic environment, 25, 17 carbon cycle and, 25, 22, 23, 24, 31 production ecology and, 25, 6-9, 13, 15 and source of atmospheric oxygen, 28-29, 54-5, 58, 61 pH scale, 15*, 27-8, 29, 30, 38-9 phyllite, 27*, 49, 51, 52, 54; 28-29, 4 phylum, 21*, 29, 31, 32, 33; 26, 3, 15 physical states, changes in, 16, 5, 6 physical system, 9, 6 physical weathering, 27*, 16, 31, 32, 44 physico-chemical factors, 25*, 3 physics, 3*, 4 physiology, 22*, 3–4, 64; 23, 4; 26, 9–12 see also circulatory systems; control mechanisms; glucose levels; metabolism; oxygen supply Phytomyza illicis see holly leaf miner phytoplankton, 25*, 5, 6, 12, 16-17, 30; 26, 12, 13, 18 see also plankton P, see inorganic phosphate π , definition of, 2*, 17 Pickett, John, 17-18, 49 heart, 23, 12, Plate 9 insulin from, 24, 46 pigmentation, 26, 8 pillow lavas, 5-6*, 76, Plate 16; 28-29, 22 pituitary, 23, 32 Placet, P., 7-8, 17 plagioclase feldspar, 27*, 9, 10, 11, 15, 29, 32 Planck, Max, 10, 45 Planck's constant, 10*, 45, 46-7, 50; 30, 7, 10, 21, 27-8; 31, 6, 12, 13, 16 and Heisenberg's uncertainty principle, 30, 28 planes, inclined, Galileo's experiments with, 3, 8-9 plane of lunar orbit, 1, 35-8, 43 plane-polarized light, 17-18*, 57, 58-9, 62-3, Plates 6-8 planets, 1*, 18, 45; 2, 30-41; 28-29, Copernican system, 2, 30-2 cores of, 28-29, 45, 49, 50, 51

density of, 28-29, 39, 41, 47-8 formation, 28-29, 42-51 accretion, heating and layering, 28-29, 47-50, 57 Jupiter, moons of, 2, 42-3 meteorites, evidence from, 28-29, 42-7, 50 paths/orbits of, 1, 18, 22, 32-3, 45; 2, 30-1, 32, 34-6 time (after Big Bang) when formed, 32, 45 Tycho Brahe's tables, 2, 33, 35, 36 Uranus, Neptune and Pluto, 2, 34, see also Kepler planetary model of the atom, 11-12, plane wave, 10*, 25, 26, 30 plankton, 28-29, 75; see also phytoplankton; zooplankton planning experiments, 4, 6–7, 28 plants, 19, 4–5; 28–29, 67, 68, 70 adaptation, 19, 15-16 animals eating see herbivores carbon dioxide and, 28-29, 58, 78 cells, 19, 5-8; 22, 38, 39; 26, 4, 15 genetic engineering of, 24, 46 classification, 21, 27, 29 copper tolerance, 21, 9, 10 evolution by natural selection, 19, 32-6 fecundity and viability, 19, 22-4 fitness, 19, 22-3, 32-6 flowering, 19, 11; 22, 4 genetic variability, 21, 14 mutation of, 19, 31 rabbits and, 25, 60-2 recombination, 21, 20 speciation, 21, 22, 25-6 vegetation belts, 7-8, Plate 4; 28-29, 71 see also autotrophs; individual plant names; photosynthesis plant respiration (R), 25*, 8, 18 see also respiration **plasma**, blood, **23***, 11, 18, 19, 20, 22, 24, 33; **26**, 11 enzyme assay, 22, 32 pH, 22, 29 plasmids, 24*, 47, 48 Plasmodium falciparum (malarial parasite), 21, 18; 25, 4 plastic deformation of rocks, 27*, 47, 54 plasticizers, 17-18*, 85 plastics, 17-18, 4, 78 see also giant molecules; macromolecules plate margins, 7-8, 52, 55, 72; 28-29, 80 and metamorphism, 27, 51 and origin of andesites, 27, 24-7, 28, 29 and origin of basalts, 27, 20-1, 25, 26, 29 see also conservative; constructive; destructive plate tectonic theory, 7-8*, 59; 31, 28 before revolution, 7-8, 17-26 see also continental drift revolution, 7-8, 26-59, 79-82 apparent polar wandering, 7-8, 27 chronology, 7-8, 81

collision, 7-8, 72, 74 and continental drift, 7-8, 56-9 deep-sea drilling, 7-8, 47-50 geopoetry, 7-8, 38-40 global tectonics, 7-8, 52-6 heat-flow measurement, 7-8, 36-7 magnetic anomalies measured, 7-8, 40-7 ocean depths and continental fits, 7-8, 27-9 transform faults, 7-8, 51-2 platelets, 23*, 18, 20, Plate 10 platinum-iridium standards of length, 2, 6 of mass, 2, 9 Pleistocene Period, 28-29, 23 Pliocene Period, 28-29, 23 ploughing and biogeochemical cycles, **25**, 23–4, 27, 31 Pluto, **28–29**, 37, 38–9, 41 orbit of, **1**, 45; **2**, 34, 40 pluton, 27*, 22, 50 plutonic rocks, 5-6*, 8, 76, 77, 79; 27*, 22, 23-4, 29 see also intrusive rocks plutonium, 13-14, 39, 41, 75 Pohlflucht (flight from poles), 7-8, 23 point-like particles, 32, 3, 25 see also fundamental particles polar front, 28–29*, 74, 75 Polaris, 1*, 18, 22, 40–1 polarity magnetic, 7-8, 11, 44-5 time scale, 5-6, 86-7 polarized light, 17-18, 57-9, 62-3, 66, Plates 6-8 polarizer, 17-18, 57-8, Plates 6-8 Polaroid material, 17-18, 57, 58 polar solvents, 13-14*, 68; 17-18, 23 polar wandering, apparent, 5-6, 84-6; 7-8, 27, 58 poles geographic, 5-6, 44, 49, 55 palaeomagnetic, 5-6, 55, 83, 84, 87 of a bar magnet, 5-6, 44, 45, 51 see also geomagnetic poles pole of rotation, 7-8, 52-4, 58 pollen, 20*, 3, 4, 5, 8, 17, 23, 28, 30 pollination, 19, 4-5; 20, 3 pollution of environment, 15, 31-3, 25, 27, 29, 30-1, 32 and colour of moths see peppered moth and mutation, 21, 5 oil, 26, 14 resistance to, 21, 9, 10 polyamides, 17-18*, 82, 88 polyatomic ions, 13-14*, 49, 56, 57, 62 polyatomic molecules, bond energies for, 16, 12, 14 polydeoxyribonucleotides, 17-18, 90; 24*, 10 polyester, 17-18*, 4, 78, 82, 86, 87, 90, Plates 3, 9 and 10 polyethylene see polythene polyethylene terephthalate (PET), 17-18, 87 polymers, 17–18*, 4–5, 78 strands in DNA, 24, 10, 12 synthetic RNA, 24, 36, 37, 38 see also addition polymers; biopolymers; condensation

polymers (continued)
polymers; giant molecules;
polymerization polymerization, 17–18*, 78, 95
addition, 17–18, 78–81, 90, 96
condensation, 17–18, 81–2, 89 polymorphism, 21*, 16–18, 19, 22
polymorphism, 21*, 16–18, 19, 22 polynucleotides, 17–18*, 89, 90; 19, 10
polypeptides, 17–18*, 88; 22*, 21–2,
24; 26 , 8, 17, 18
chain synthesis, 24 , 29, 34, 37–8
polypropylene, 17–18 , 79, 85, 86, 87, 95, Plate 10
polyribonucleotides, 24*, 24
synthetic, 24, 37
polysaccharides, 17–18*, 89; 22, 7, 15, 17–20, 64; 26, 10, 11, 18
polysomes, 24*, 29, 30; 26, 15
polystyrene, 17–18, 79
polythene (polyethylene), 17–18, 79, 85, 95, 96
poly(U), 24, 36
poly(vinyl chloride), (PVC), 17-18,
79, 85, 104 pond see aquatic ecosystems
Pongidae, 21, 31
pons, 23*, 33
Popper, Sir Karl, 1, 6; 7–8, 80 population, 19*, 22; 25*, 5; 26, 6, 8,
13, 14, 17, 19
defined, 21, 4
ecology of, 25 , 33–56 density changes, 25 , 33–9
evolution proceeds by, 21, 28
growth, 19, 4, 22, 24
mortality factors and k-value analysis, 25, 39–44
holly leaf miner, 25, 45–53
see also animals; biological
control, genetic variability; humans; plants; speciation
population density, 25*, 33, 34-5
see also biological control porpoises, adaptation by, 19, 13–14
position, components of, 30, 24, 25,
26-9, 31, 32
position isomers , 17–18* , 30, 31, 32–5, 53
positive charge, 9, 30-1, 33
of ions, 11–12, 5, 7–8, 9, 12, 13,
14–16, 18, 37, 66, 69 and atomic spectra, 11–12, 28,
35, 36
positive feedback, 23*, 29; 26, 11
positron, 31, 30, 31, 36; 32, 14–17 post-transcriptional modification, 24*,
44, 46–7
post-translational modification, 24*,
38, 46–7 potassium, 13–14, 42
chemical bonding, 13-14, 58, 65
in oceans, 28–29 , 59–60, 61 in rocks, 27 , 6, 8, 20, 21, 22–3, 40;
1n rocks, 27, 6, 8, 20, 21, 22–3, 40; 28–29, 44, 46, 53
feldspars, 27, 9, 10, 11, 20, 42
isotopes, 27, 18, 19; 28–29, 27,
30, 31, 50 transport and deposition of, 27,
41
potassium carbonate, 13–14, 49 potassium chloride, 13–14, 72
potassium dichromate, 13–14, 72
potassium iodide, 13-14, 42-3, 51, 56
potential difference, 9*, 33

potential energy, 9, 2; 31, 7
power, 9*, 34, 35
geothermal, 7-8, 69
stations, 9, 4–5
see also fuel; nuclear energy
powers-of-ten (scientific) notation, 2*,
10
practical work and experiments
designing, 4, 4–6
measurement, 4, 4, 17–20
observation, 4, 4
planning, 4, 6-7, 28
records of, 4, 7-10
rehearsing, 4, 7
reports, writing, 4, 27–34
see also data
prebiotic chemistry, 17-18, 91-5
carbon compounds, 17–18, 91–2
optical activity, origin of, 17-18,
92–3
Precambrian Era, 28-29, 4, 57, 64-6
dating, 28-29, 35
fossils in, 28–29 , 25, 54, 64–6
ice age in, 28-29, 72
life in, 28–29, 63, 64–7
in Stratigraphic Column, 28-29,
20–1
see also banded ironstone
formations
precipitate, 15*, 16
precipitation (climatic) see rain
precipitation, direct chemical, 27, 41,
45
precise measurement, 4*, 17, 18, 20
precision, standard of, 2, 6
precursors, 22*, 7, 9, 62, 64
precursor molecules, 24, 46-7
predators, 19, 13, 15, 22, 24; 25, 5, 11,
12
for biological control, 25, 53, 55
birds as, 19, 17-19
on shore community, 25, 58
prediction
of earthquake, 5-6, 91-3
of undiscovered elements, 13-14,
30, 33
pre-pro-insulin, 24, 46–7
pre-reproductive mortality, total
generation, 25, 40, 41, 55
pressure, 5–6*, 10, 60, 75
blood, 23, 35
constant in endothermic and
exothermic reactions, 16, 4
equilibrium yield and, 16, 31, 32
water, solubility of oxygen and, 23,
)
prey see predators
primary alcohols, 17–18*, 72, 76
primary atmosphere, 28-29, 57
primary atmosphere, 28–29, 57 primary producers, 25*, 7, 8–11, 18;
primary atmosphere, 28–29 , 57 primary producers , 25* , 7, 8–11, 18; 26 , 12
primary atmosphere, 28–29 , 57 primary producers , 25* , 7, 8–11, 18; 26 , 12 seasonal changes and, 25 , 24–5
primary atmosphere, 28–29, 57 primary producers, 25*, 7, 8–11, 18; 26, 12 seasonal changes and, 25, 24–5 see also gross primary production;
primary atmosphere, 28–29, 57 primary producers, 25*, 7, 8–11, 18; 26, 12 seasonal changes and, 25, 24–5 see also gross primary production; net primary production
primary atmosphere, 28–29, 57 primary producers, 25*, 7, 8–11, 18; 26, 12 seasonal changes and, 25, 24–5 see also gross primary production; net primary production primary structure of proteins, 22*, 21,
primary atmosphere, 28–29, 57 primary producers, 25*, 7, 8–11, 18; 26, 12 seasonal changes and, 25, 24–5 see also gross primary production; net primary production primary structure of proteins, 22*, 21, 22–4; 26, 10, 17, 18
primary atmosphere, 28–29, 57 primary producers, 25*, 7, 8–11, 18; 26, 12 seasonal changes and, 25, 24–5 see also gross primary production; net primary production primary structure of proteins, 22*, 21, 22–4; 26, 10, 17, 18 primary waves see P-waves
primary atmosphere, 28–29, 57 primary producers, 25*, 7, 8–11, 18; 26, 12 seasonal changes and, 25, 24–5 see also gross primary production; net primary production primary structure of proteins, 22*, 21, 22–4; 26, 10, 17, 18 primary waves see P-waves primates, 19, 5
primary atmosphere, 28–29, 57 primary producers, 25*, 7, 8–11, 18; 26, 12 seasonal changes and, 25, 24–5 see also gross primary production; net primary production primary structure of proteins, 22*, 21, 22–4; 26, 10, 17, 18 primary waves see P-waves primates, 19, 5 primordial atmosphere, 17–18, 91–2
primary atmosphere, 28–29, 57 primary producers, 25*, 7, 8–11, 18; 26, 12 seasonal changes and, 25, 24–5 see also gross primary production; net primary production primary structure of proteins, 22*, 21, 22–4; 26, 10, 17, 18 primary waves see P-waves primates, 19, 5 primordial atmosphere, 17–18, 91–2 primordial heat, 27, 19, 29
primary atmosphere, 28–29, 57 primary producers, 25*, 7, 8–11, 18; 26, 12 seasonal changes and, 25, 24–5 see also gross primary production; net primary production primary structure of proteins, 22*, 21, 22–4; 26, 10, 17, 18 primary waves see P-waves primates, 19, 5 primordial atmosphere, 17–18, 91–2 primordial quantum number, n, 11–12*,
primary atmosphere, 28–29, 57 primary producers, 25*, 7, 8–11, 18; 26, 12 seasonal changes and, 25, 24–5 see also gross primary production; net primary production primary structure of proteins, 22*, 21, 22–4; 26, 10, 17, 18 primary waves see P-waves primates, 19, 5 primordial atmosphere, 17–18, 91–2 primordial heat, 27, 19, 29 principal quantum number, n, 11–12*, 32, 43, 46, 58; 13–14, 34
primary atmosphere, 28–29, 57 primary producers, 25*, 7, 8–11, 18; 26, 12 seasonal changes and, 25, 24–5 see also gross primary production; net primary production primary structure of proteins, 22*, 21, 22–4; 26, 10, 17, 18 primary waves see P-waves primates, 19, 5 primordial atmosphere, 17–18, 91–2 primordial quantum number, n, 11–12*,

```
principle of superposition (waves),
       10*, 17, 18-24, 25
  see also superposition
principle of superposition (Earth
       sciences), 28-29*, 14, 25
principle of uniformitarianism,
       28-29*, 19, 22, 25, 66
  theories of origin of Solar System,
       28-29, 37
principles of regulation see control
       mechanisms
probabilistic interpretation
  of diffraction pattern, 30, 14-17,
       27, 33
  of wavefunction, 30, 19-21
processes of life, 19, 10-11
producer see primary producer
products, 13-14*, 9, 25; 26, 10
production ecology, 25*, 6-18
  see also primary producers and
       ecosystems
pro-insulin, 24, 46-7
prokaryotes, 19*, 9, 11; 21, 29; 24,
       45-6
  time when appeared, 28-29*, 59,
       63, 64-5, 69; 32, 45
  see also bacteria
proline (Pro), 22, 21; 24, 36
propagation, 30, 10
  of free matter see de Broglie's
       formula; wavefunctions
  quantum behaves as wave in, 30,
       12, 13, 17
propanal, 17-18, 42
propan-1-amine, 17-18, 21
propane, 17-18, 18-19, 27
propanoic acid, 17-18, 72, 94
propan-1-ol, 17-18, 20, 23, 31-2, 57,
       68, 70, 72
propan-2-ol, 17-18, 31, 57, 72
propanone see acetone
propanoyl chloride, 17-18, 70
propene see propylene
prophase in meiosis, 20, 13, 14, 16,
       20, 21, 29, 34, 46, 48; 26, 5, 15,
  compared with mitosis, 20, 46, 48
proportionality, 2*, 40, 41
propyl acetate, 17-18, 68, 70
propylene, 17-18, 38, 39, 43, 45, 79,
       96
propyne, 17-18, 38
prospecting, magnetic and seismic
       techniques in, 5-6, 88-9
prosthetic groups, 22*, 25
proteins, 17–18*, 60, 69, 74, 88–9; 19, 8–9, 11; 22, 5, 20, 21–4, 25; 26,
       8, 9, 11
  carbon cycle and, 25, 26
  elements necessary for, 25, 21, 25,
       29
  fibrous, 17-18, 88; 22, 23
  functional, 24, 38
  functions, 22, 20, 24
  globular, 17-18, 88, 89; 22, 23-4,
       25; 26, 10, 18
  histones, 20, 9, 10
  meiosis and, 20, 19-20
  structure, 22, 20-4, 29, Plates 1
       and 2: 26, 10, 17, 18
  synthesis, 22, 6, 7, 38, 40; 24, 9,
       21-35, 44-5
     bacteria as 'factories' for, 24,
       45-9
```

proteins (continued) see also enzymes; messenger RNA; translation; transcription protein half-life, 22*, 5 proteolytic (protein-destroying) enzymes, 23, 27 'proto-Atlantic Ocean', 7-8, 57 **proton**, **11–12***, 16, 17, 18, 19, 20; **31**, 3–4, 11–12, 17–18, 21, 27 baryon number, 32, 20 quarks in, 32, 26 rest mass of, 32, 7 stability, 32, 18 structure of, 32, 24-5, 42 see also atomic nucleus; strong interaction ψ see J/ψ PTFE, 17-18, 79 Ptolemy, 1, 14 P-S-P core waves, 5-6, 75 Puerto Rico Trench, 7-8, 13 pulmonary artery, 23, 13, Plate 19 pulmonary circulation, 23*, 13, 20 pulmonary vein, 23, 13, Plate 19 pumice, 5-6*, 76, Plate 17 pupae of holly leaf miners, mortality of, 25*, 45, 46, 47, 50, 51 pure-breeding plants and animals, 20*, 4, 24-6, 33, 34, 35, 41 inheritance experiments see Drosophila; maize; peas purine bases, 24*, 11, 12 PVC, 17-18, 79, 85, 104 P-wave shadow zone, 5-6*, 63, 73 P-waves, 5-6*, 26, 28, 33, 38, 78, 90 speed of, 5-6, 29-32, 61-7, 72, 73-5, 81 pyloric sphincter, 26, 10, 11, 18 pyrethroid insecticides, 17-18, 47 pyrimidine bases, 24*, 11, 12, 24 pyrite ('fool's gold'), 5-6, 76; 27, 7, 13, 14, 37, Plate 9; **28–29***, 53, 59 **pyroclastic rocks**, **27***, 19, 20 pyroxene in meteorites, 28-29*, 44, 51 in planets, 28-29, 49 in rocks, **27***, 6, 9, 10, 11, 15, 16, 20, 23, 29 weathering of, 27, 32 pyruvate decarboxylase, 22*, 57 pyruvic acid, 22*, 14, 15, 45, 46, 47, 48-50, 54, 57-8, 59, 61; 26, 15 Pythagoras: on spherical Earth, 1, 14 theorem of, 3*, 5

0

Q, coenzyme, 22, 31, 52, 55 qualitative work, 4, 4 quanta of electromagnetic radiation, 10, 45-50; see photon quantitative result, 4, 4 quantization, 10*, 45, 47, 50; 31*, 7 of energy, 11-12*, 27 of an atom, 31, 3-4, 11-16 nuclear, 31, 21-2 of wavelengths of wavefunction, 31, 5-7, 9-10 quantum, 30*, 12, 13 motion of, Heisenberg's uncertainty principle applied to, 30, 26-9, 31 theory, 30, 13

see also electromagnetic radiation; models of matter quantum chromodynamics (OCD), 32*, 29, 33, 41-2 quantum electrodynamics, 10*, 52; 30, quantum mechanics, 11-12, 12, 15; 30*, 4, 13, 14-23, 26-35; 32, 14, 38 and confined particles, 31, 3-10, 11-17, 42 and macroscopic objects, 30, 32-5 as theory of behaviour, 30, 35 compared with classical (Newtonian) mechanics, 30, 4, 23, 31, 34, 35 see also matter; wavefunctions **quantum number**, **11–12**, 32, 43, 45–6, 53–5, 57–8, 59, 62; **13–14**, 34; 31*, 5, 6-10, 15-16 and shells and subshells, 11-12, 42-3, 46 see also magnetic quantum number; second quantum number quarks, 32*, 4, 25, 26, 27-9, 42-3 antiparticles of, 32, 26-8 interactions of, 32, 28-9 and gauge bosons, 32, 41-2 model, simple, 32, 25, 26, 27, 30 quartz, 5-6*, 8, Plate 9; 13-14, 64; 27*, 5, 6, 9, 10, 11, 14, 15, 16, Plates 5 and 6 resistance to weathering, 27, 32, 33, transport and deposition of, 27, 34,36 'quasi-planetary' system, 2, 44 Jupiter and moons as, 2, 42-3 Quaternary Period Ice Age, 28-29, 72, 74, 75-6, 77, 78 in Stratigraphic Column, 28-29, 23 varves of, 28-29, 8 quoting results, 4, 21

D

rabbits (Oryctolagus cuniculus) and vegetation, 25, 60-2 racemic mixture, 17-18*, 62-3, 93 races (subspecies), 21*, 24, 25-7, 29, 31, 33 radian, 2*, 18, 20, 22, 30, 48 radiation see electromagnetic radiation; ionizing radiation radiation-induced changes in DNA, 24, 40, 41, 43, 50; 26, 5, 16; 31, 34, 35 radicals, 17-18*, 79-80, 85, 96 radioactive dating of rocks see radioactivity radioactive decay, 11–12*, 18–22; 31*, 18, 27, 28, 29–33, 37 decay chains, 31, 32-3 and fundamental particles, 32, 13, 14, 15, 28-9 half-life, 11-12, 20, 21, 22, 23; 28-29, 26-31 hazards of radioactivity, 31, 33-5 new types of, 31, 32 see also α-decay; β+-decay; β^- -decay; γ -decay; radioactivity; spontaneous nuclear fission

radioactivity, 11-12*, 18, 19-20; 15, 14; 17-18, 93 hazards of, 31, 33-5 in production ecology, 25, 12 in rocks, 27, 18, 19, 29 dating, 7-8, 18, 24, 25, 29 see also radiometric clocks see also isotopes: radioactive decay radio-astronomy, 17-18, 93 radiometric 'clocks', 28-29, 24, 26-9, 32-5, 36-7 minerals as, 28-29, 30-1 radio waves, 10, 40 radius, 2, 17, 18, 30 of Earth, 2, 15-19, 21-2, 29, 45-6; 5-6, 6, 7 of Moon, 2, 20-2, 29 of orbits of Earth and planets, 2, 30-2, 34, 36-40, 42-3 of Sun, 2, 28-9 radon, 13-14, 28, 31, 39, 58; 31, 35 Raff, Arthur, 7-8, 41 ragwort (Senecia jacobaea), 25, 61, Plate 13f rain, 15, 24 acid, 15, 30-3; 25, 30-1, 32 leaching by, 25, 27, 32 pH of, 15, 30 and weathering, 27, 31, 32, 34, 40, 44, 53 random uncertainties, 3*, 25; 4, 18, 19-20 range of fundamental interactions, 32, 16, 29 rare earth elements, 13-14*, 30, 33 rarefaction pulse (dilatation), 5-6*, 26,90 rates of chemical reactions, 16, 2, 18-28, 29 activation energy, 16, 21-5 catalysts, 16, 25-7 influences on, 16, 19 molecular interpretation of effect and concentration and temperature, 16, 20-1 rats: resistance to Warfarin, 21, 9, 10 reactants, 13-14*, 9, 20, 25 reaction see chemical reactions; condensation reactions; endothermic reactions; enthalpy; exothermic reactions; nuclear reactions reaction-coordinate diagrams, 16*, 23, reaction mechanism, 16*, 19 reading frame, 24, 41; 26, 17 reagents, 17-18, 71, 73 realized niche, 25*, 59, 62 receptors, 23*, 28, 31, 33, 34, 37 pH-sensitive, 26, 18 stretch, 23, 34, 35; 26, 18 receptor sites, chiral and non-chiral, 17-18, 62 recessive allele and character, 20*, 27, 30, 38, 41; 21, 4, 6-8, 10, 11, 17; 26, 5, 6, 16 molecular explanation of, 24, 42-3 reciprocal, 2, 10 recombination of genes, 20*, 44; 21, 19-21, 22; 26, 5, 15 see also crossing over; genetic variability; independent assortment

records, 4, 7-8

DNA makes, 24, 4, 23, 24-6 redbeds, 28-29*, 53, 57 residual minerals, 27*, 33 red blood cells, 19, 6, 7; 21*, 16, 18; makes protein, 24, 4, 22 resistance 23*, 11, 18, 19, 20, 21, 22, 24, to insecticides, 17-18, 47 polymers, synthetic, 24, 36, 37, Plate 10; 26, 11 to malaria, 21, 18-19 38 of minerals to weathering, 27, 32, and glucose, need for, 23, 26 see also messenger RNA; 33, 44 ribosomal RNA; transfer red fescue grass (Festuca rubra), 25, 61 phenotypes, 19, 26 RNA reduction, 17-18*, 70, 71, 72-3, 76 to pollution, 21, 9, 10 roach (Rutilus), 25, 17, Plate 4 of rats to Warfarin, 21, 9, 10 rocks, 5-6, 5, 8; 27*, 5 reed, common (Phragmites australis), 25, 4, Plate 3b respiration (cell), 22*, 3, 10, 12, 39, 62 age, 7-8, 12, 16, 20, 28, 29 aerobic, 22, 10 reference levels, 23*, 28, 31; 26, 11, 18 dating from deep-sea drilling, anaerobic, 22, 57 7-8, 49-50 reflection beginning of, 28-29, 55, 65 angle of, 5-6, 34 see also radioactivity carbon cycle and, 25, 22, 23, 24, 31 catastrophism and, 28-29, 16, 19, seismic, 5-6, 34-7, 64, 79, 88-9 reflection of a wave, 10*, 4, 5 measuring, 22, 41-2 26, 50, 51 photosynthesis and, 22, 62 chemical composition of, 27, 18-20 reflection profile, 5-6*, 88-9 refraction production ecology and, 25, 8, 13, climates, past, evidence in, 7-8, 18-19, 20-1, 26, 56-7 angle of, 5-6, 33, 34 18 heat from, 25, 7, 8, 9, 14-15, 17 density, 5-6, 10-11, 12, 60, 63-5, critical, 5-6, 72-3 seismic, 5-6, 33-7, 64-5, 72-5, 78 see also catabolism 81 folding, 5-6, 12; 7-8, 22, 70 respiration (gaseous exchange), 23, refraction of a wave, 10*, 4, 6 refrigerants, 17-18, 9, 13-15, 16 8-9, 10, 21-2 horizontal/lateral movements, 7-8, regeneration, cyclical, 25, 60, 62 control mechanisms of, 23, 32-3, 24-5, 43, 73, 74 34, 37 igneous see igneous rocks regional metamorphism, 27*, 50, 51, see also oxygen supply rest mass, 31*, 24, 26-7 investigating structure of, 32, 6 52, 54 ionizing radiation from, 31, 35 regular solids, five, 2, 34 regulating mortality factor, 25*, 42 magnetism, 5-6, 82-8 of gauge bosons, 32, 39, 40, 41, metamorphic, 5-6, 79 regulation, 23, 4 42-3 of glucose catabolism, 22, 58-9 of hadrons, 32, 7, 18, 22, 32, 33-4, paleomagnetism, 5-6, 54-5, 58 and soil, ionizing radiation from, principles of see control 36 of leptons, 32, 13-14, 15, 34-5, 31, 35 mechanisms 42-3 time when formed, 32, 45 regulatory effect of weathering of, 25, 21, 23-4; 28-29, density-dependent mortality of quarks, 32, 26, 31, 34, 43 and natality rates, 25, 37 results see also crust; density; geology; regulatory enzymes, 22*, 58 quoting, 4, 21 reporting, 4, 27-34 igneous; metamorphism; rehearsal for experiment, 4, 7 relationship, evolutionary see retrograde loops, 1*, 18, 22, 32-3 minerals; rock texture; sedimentary; silicate minerals; reversals of magnetic polarity, 5-6, classification relative abundances, 11-12*, 10 56, 86-7 rock cycle, 27*, 4, 53-4 reverse faults, 27*, 48, 49, 54 rockets and energy, 16, 33-5 relative atomic mass, A, 11-12*, 10, 72; 13-14*, 14, 16, 29, 79 revolutions, scientific, 7-8, 79-80 rock-stratigraphic column, 28-29*, 24 relative dating method, 28-29*, 12, see also plate tectonic theory R group of amino acids, 22*, 21, 22, see also Stratigraphic Column 32 - 3, 35rock texture, 5-6, 8-9; 27, 49 relative molecular mass, 17-18*, 11 rhesus factor in blood, 21, 11-12 rodents relativistic quantum mechanics, 30, 32 rhyolite, 5-6*, 76, Plate 19; 7-8, 73; density of population, 25, 43 relativity 27, 28, 29 resistance to Warfarin, 21, 9, 10 general theory, 32, 15 riboflavin, 22, 32 seed-eating, 25, 58-9 special theory, 3, 15; 10, 44-5, 48; 30, 5, 9, 32; 31, 15, 24, 27, 42; ribonucleic acid see RNA Romanche Fracture Zone, 7-8, 51, ribonucleotides, 24*, 24, 25 32, 6, 7, 14, 38 ribose, 24*, 24 Rookhope borehole, 28-29, Plate relief of the Earth, 5-6*, 6 ribosomal RNA (rRNA), 24*, 32, 42, remote sensing, 5-6*, 6, 68, 90; 29 **28–29***, 80, Plate 32 **replication**, **19***, 10, 11, 37 45; 26, 8 roots hairs, 22, 10 structure of, 24, 24 ribosomes, 22*, 6, 38, 39, 40, 41, Plate tip, 22, 14 DNA, 24, 14, 17-21, 50 5; 24*, 22; 26, 8, 15 rotation semi-conservative, evidence for, of compact disc, 1, 19 and protein synthesis, 24, 22-3, 29, 24, 19-20 pole of, 7-8, 52-4, 58 32, 33, 34 theoretical scheme for, 24, 17-19 specific, 17-18, 59 Richter, Burton, 32, 33, 34 reports, 4, 27-34 Richter scale, 5-6*, 19, 20, 21 see also axis of rotation; Earth representations of a wave, 10*, 14, 16, ridge-push force, 7-8*, 78, 79 rotational motion, 9, 17 23-4 Rothamsted Experimental Station, reproduction, 19*, 10, 11, 21, 32, 37; ridges see Atlantic; oceans; Pacific 17-18, 49 rifts, 7-8, 68 26, 4 Rowland, F. Sherwood, 17-18, 15 see also axial rift by cell division, 28-29, 63, 64 rRNA see ribosomal RNA right-angled triangle, 2, 32 potential, 19, 22-3 'right-handed' forms see chirality Rubbia, Carlo, 32, 40-1 see also fecundity; meiosis; mitosis rigidity modulus, 5-6*, 31-2, 60, 65 Runcorn, Professor Keith, 7-8, 80, reproductive isolation, 21*, 23, 24-6; Rio Grande Fracture Zone, 7-8, 51 26, 8 rust/rusting, 13-14, 5; 17-18, 70 reptiles, 28-29, 11-12, 67, 70 ripples, 27, Plate 13 see also water waves Rutherford, Ernest, 11-12, 12-14; 32, excretion, 23, 23 24 repulsion of charged atoms, 9, 31-2, risks of ionizing radiation, 31, 34-5 on nuclear power, 31, 39 river, ecosystem, 25, 16-17 33, 34; 11-12, 5, 14, 15 RNA, 17-18*, 89; 19, 9, 10; 22, 6, 64; Rutherford atomic model, 11-12*, repulsive electrostatic force, 9, 31-2,

24*, 22, 24-35, 50

15

33, 34

S

Salam, Abdus, 32, 40, 41 saliva, 22, 33; 26, 9, 10, 18 salivary amylase, properties of, 22, 33-5, 37, Plate 3 salt, 15*, 9, 10 as electrolyte, 15, 18 in solution, 23, 5, 18 sampling, 4, 4-6, 16 San Andreas Fault System (SAFS), 5-6, 15, 92-3, Plates 2a and 2b; 7-8, 73-4 sand, 27, 36, 37; 28-29, 7 dune, 27, Plate 13 interglacial, 28-29, 74 sandstone, 5–6*, Plates 5 and 6; 7–8, Plate 5; 27, 9; 28–29, 4, 14, 20-1, 22, 23, 53, 60 fossils in, 28-29, 18, 65 satellites and Earth sciences, 5-6, 6 remote sensing, 7-8, 76, 77 saturated compounds, 17-18*, 38 saturated solution, 15*, 12, 13, 20 Saturn, 28-29, 38-9, 41 orbit of, 1, 45; 2, 31, 36, 38, 40 scale of graph, choosing, 4, 13, 14-15, 24 Scandinavia: isostatic readjustment, 7-8, 32, 33 scandium, 13-14, 28, 29, 31-2, 36-9 scanning electron microscopy, 17-18, 86; 19, 6 scattering of photons see Compton effect Scilly Isles, 26, 13-14 Schimper, William, 28-29, 23 schist, 27*, 49, 51, 52, 53, 54; 28-29, 4, 18 Schistosoma (parasitic worm), 19, 5 schistosomiasis, 19, 5 Schleiden, Jacob Mathias, 19, 6 Schrieffer, John, 30, 34 Schrödinger, Erwin, 30, 22 Schrödinger equation, 30*, 22; 31, 4, 15, 17 Schwann, Theodor Ambrose Hubert, 19, 6 Schwinger, Julian, 10, 52 science as social activity, 1, 5-6, 10 scientific method, 1, 6-8 scientific (powers-of-ten) notation, 2*, 10 scientists as social group, 1, 6 seas see oceans Seaborg, Glenn, 13-14, 41 sea-floor spreading, 5-6, 87; 7-8*, 38, 39, 40, 44-7, 49-50 see also ocean; crust seamount, 7-8*, 10 seashore see shores seasons, 1, 16, 22, 24 cause of, 1, 28-32, 41 sea urchin, 28-29, Plates 22a and 22b seawater, pH of, 15, 30 seaweeds, 25, 57 second, 2*, 8, 11 second carnivores, 25, 12, 14 second filial generation (F2), 20*, 5, 6-7, 23, 28, 30, 33, 37-40, 41-4 second quantum number, l, 11-12* 43, 46, 58; 13-14, 34; 31, 15 secondary alcohols, 17-18*, 72

secondary waves see S-waves section, geological, 28-29, 18-19, 20 - 1secular variations of Earth's magnetic field, 5-6*, 53 Sedgwick, Adam, 28-29, 22, 23 sedimentary rocks/sediments, 5-6*, 9, 12, 79, 83; 27, 5, 11, 15–16, 31-45, 52-3, Plate 1; 28-29, 53 bed forms and structures, 7-8, Plate 5, 27, 38-9, Plate 1; 28-29, 8, 14, 24, 32 deposition of, 7-8, 6, 21; 27, 35-6, 38-41, 45, 53 similar sequences of, 7-8, 28, 29 coal, 7-8, 21, 56-7 erosion of, 7-8, 7 evidence of latitudinal drift in, 7-8, 56-7 on ocean floor, 28-29, 74-5, 79 plate margins and, 7-8, 63, 64, 72 sunspot activity indicated by, 28-29, 77 and tectonic process, 27, 46-8 transport and deposition of, 28-29, 5, 19, 22, 60, 61 varves, 28-29, 7-8 see also erosion; deposition; fossils; Stratigraphic Column; transportation; weathering seed-eating rodents, 25, 58-9 segregation (separation) of alleles in meiosis, 20, 28 seismic activity, 7-8, 12, 16 on borders of Pacific, 7-8, 14, 25, 34-6 gravity anomalies and, 7-8, 33-4, 35-6, 38 plate margins and, 7-8, 55-6, 66, 67, 71, 73-4, 76, 79 transform faults, 7-8, 51-2 see also earthquakes; volcanic activity seismic discontinuity, 5-6*, 65, 78, 81 see also Mohorovičić discontinuity seismic energy, 5-6*, 25, 89 seismic evidence of planet formation, 28-29, 42, 47 seismic model of the Earth, 5-6, 61-5 seismic reflection, 5-6, 34-7, 64, 79, 88-9 seismic refraction, 5-6*, 33, 34-7, 64-5, 72-5, 78 seismic trace, 5-6*, 18, 19 seismic waves, 5-6, 24-38; 10, 4 speeds of, 5-6, 29-32, 33, 35, 36, 37, 38, 60-8, 81 types of, see P-waves; S-waves wave motion, 5-6, 23-4 see also earthquakes; reflection, seismic; refraction, seismic seismic zones, 5-6*, 16 seismogram, 5-6, 18, 28, 38 seismology, 5-6*, 17, 37-8 seismometer, 5-6*, 17, 18, 24, 26, 37, 88, 89 selection for and selection against, 19, 32 see also natural selection 'selectionists', 21, 16 selectively neutral, 21*, 15, 22 self-conjugate fundamental particles, 32, 39

self-exciting dynamo model, 5-6*, 71, 87 SEM see scanning electron microscopy semiconductors, 13-14*, 69 semi-conservative replication, 24*, 19-20, 21 semi-metals, 13-14*, 30-1, 69, 76 sensory nerves, 23*, 34 serine (Ser), 17-18, 60; 22, 21; 24, 36 sewage effluent and algae growth, 25, 27 works and phosphorus cycle, 25, 29, 30, 32 sex-attractant pheromones, 17-18, 48-9 shadows, 10, 6, 7 'shake' waves see S-waves Shap area, 28-29, Plates 27 and 28 Shatsky Rise, 7-8, 37 shearing motion, 5-6, 27, 28 see also S-waves shear strain, 5-6*, 31 shear stress, 5-6*, 31 sheep in Tasmania, 25, 33 shells see electron shells shield volcano, 7-8*, 68, 27, 19, 29 shores/coastal areas, 26, 14 communities, 25, 4, 57-8 rocks in, 27, 33, 36-7, 39 sickle-cell anaemia, 21, 16-19; 22, 6, 23; 24, 40 signals, 23*, 28, 31, 32, 33 significant figures, 4*, 21 silica, 13–14, 64; 27*, 6, 8, 11, 22–3, 40 silicate minerals, 27*, 6, 7-9, 18, 20, 24, 28; 28-29, 52-3 crystallization of, 27, 9-11 densities of, 27, 11-15, 16, 28 investigation, 27, 12-14 distribution in crustal rocks, 27, 15-16 in meteorites, 28-29, 50, 51 oxidized, 28-29, 52-3, 55-6, 57, 58 in planets, 28-29, 39, 44-6, 47-8, 49, 50 transport and deposition of, 27, 36 - 7weathering of, 27, 32-44 silicon, 28-29, 46 chemical bonding, 13-14, 64, 65, 69 chips, 17-18, 5 in oceans, 28-29, 59 in rocks, 27, 6, 8, 11, 22-3, 40 silicon dioxide, 13-14, 64 silk, 17-18, 86 sill, 28–29*, 32, 33 silt, 28–29, 7–8, 13 Silurian Period fossils in, 28-29, 12, 67 in Stratigraphic Column, 28-29, 20-1, 23 silver, 13-14, 30, 69 in rocks, 27, 6 simple quark model, 32*, 25, 26, 27, 30 sine (sin), 2*, 32 sine waves see infinite sine waves single bonds, 13-14*, 61, 62 see also catenation single-celled organisms, 19, 6, 9, 11; 21, 29; 23, 5-7, 10; 24, 45-6; 28-29, 59, 63, 64-5, 69

single-slit diffraction, 10, 6, 7, 8–9,
26–8; 30 , 14–17, 26–8, 33–4 singular statements, 1 , 7
sinker effect, 7–8*, 78, 79
SI units, 2*, 6, 7, 9, 11
size of atoms, 11–12, 6–7, 11 skeletal isomers, 17–18*, 31, 33, 34,
35, 53
SLAC (Stanford Linear Accelerator
Centre), 32 , 8, 10, 24–5, 28, 32–5
slate, 27*, 49, 51, 52, 54; 28–29, 18,
20-1
small-angle approximation, 2*, 19 smelting ore, 13–14, 74
Smith, William, 28–29, 11, 16, 17–19,
21, 25, 34
snails, marine, 19, 5
SNC meteorites, 28–29 , 80 Snell's law, 5–6* , 33, 34, 35
Snider, Antonio, 7–8, 17
snooker game, 9, 20-2
social activity, science as, 1, 5–6, 10
social group, scientists as, 1, 6 sodium, 11–12, 5; 13–14, 25, 42, 50,
52, 58, 72, 73, 76
atom, energy levels of, 11-12, 45,
49; 31, 16
atomic mass and number, 11-12, 24 atomic spectrum, 11-12, 36; 17-18,
59
chemical bonding, 13-14, 58, 59,
65, 68–9 electron shells, 11–12 , 44
electron spin, 11–12, 57
emission spectrum, 11-12, 45, 50
energy-level diagram, 11–12, 45,
49; 31 , 16 ionization energies, 11–12 , 37–8, 64
ions, excreted, 23, 26
isotopes, 11-12, 22; 28-29, 27
light, 2, 7; 17–18, 58–9
mass spectrum, 11–12, 10 in oceans, 28–29, 59–60, 61
photoelectron spectrum, 11–12, 48
in rocks, 27, 6, 8, 10, 11, 17, 20, 21,
22–3, 40; 28–29 , 53
transport and deposition of, 27,
salts, 17-18, 23, 62
sodium borohydride, 17–18, 73
sodium bromide, 13–14, 42–3, 51, 56 sodium carbonate, aqueous solution,
15, 9
sodium chloride, 13-14, 42-3, 72, 76
in solution as electrolyte, 15, 18
chemical bonding, 13–14 , 57, 65, 66–8
crystal, 13–14, 52
as ionic substance, 13-14, 45, 48,
49–50, 51, 52, 54, 55, 56
production of, 15, 9, 10 in solution, 15, 5, 27
electrolyte, 15, 18
saturated, 15, 12–13 solubility of, 17–18, 23
solubility of, 17–18, 23
sodium hydroxide, 13–14, 49, 63; 15, 5, 8
in solution, 15 , 6, 15–16, 20
as electrolyte, 15, 7, 18
pH of, 15, 27, 30
sodium sulphate, 13–14, 42 as ionic substance, 13–14, 45, 48,
49–50, 51, 56

```
soil, 25, 10
  biogeochemical cycles and, 25, 20,
       23, 25, 27, 28
  energy stored in, 25, 15, 18
  ionizing radiation from, 31, 35
  leached, 25, 27, 32
  micro-organisms in, 25, 11
solar see Sun
solar day, 1*, 16, 22
  mean, 2, 8
solar cells, 10, 53
solar eclipse
  annular, 2, 28
  total, 2, 28
solar energy flux, 25, 7-8
solar neutrinos, 32, 14, 16, 43, 44
solar radiation, 25, 7-8, 20
  aquatic environment and, 25, 16-17
  carbon cycle and, 25, 25
  production cycle and, 25, 7-8, 9,
       15, 18
solar spectrum, 11-12*, 26, 27, 70-1
Solar System, 1*, 41, 44, 45
  origin of, 28-29, 37-41
     characteristics of, 28-29, 37-40
     nebular and catastrophic
       theories, 28-29, 37, 40-1, 48
      see also planets
  measuring
     Earth, 2, 14-20, 29, 44-6
     Jupiter's moons, 2, 42-4
     Moon, 2, 20-6, 29
     planets, 2, 30-41
     Sun, 2, 26-8, 29
solar year, 1, 22
solenoid, 5-6*, 70, 71
  and chemical reactions, 16, 2, 3, 14,
       15
   elasticity and ductility of, 7-8,
       32-3, 34, 76
  internal energy of, 9, 27-9, 30
solstice, 1, 16
solubility, 15*, 12; 17-18, 23, 24
soluble products of weathering,
        transport and deposition of,
        27, 40-1
solute, 13-14*, 43
solution, 13-14*, 43; 15, 18-20; 23, 18
   neutral, 15, 5, 27
   oxygen in, 23, 5, 7, 8, 9, 10, 35
   saturated, 15, 12, 13, 20
solvents, 13-14*, 43, 51, 53, 57; 15,
       24-33; 17-18, 23-4
   ion product of water, 15, 25-7
  pH scale, 15, 27-30
  polar and non-polar, 13-14, 68
somatic cells, 20*, 11, 17; 21, 14-15;
        24, 7-8; 26, 15
   mutation and, 24, 40
   number of chromosomes see
       diploid
   see also mitosis
sorting, of sedimentary material, 27*,
        36, 45
sound energy, 9*, 3, 5
sound waves, 10, 4, 5, 6
South America, 7-8, 10, 57
   crustal plate, 7-8, 54, 55, 60, 61
   formation of, 7-8, 38
   sediments in, 7-8, 20, 29
 Southern, H. N., 25, 37, 42-3
Southern Hemisphere, 1, 16
```

seasons in, 1, 31

```
south pole of a magnet, 5-6*, 44
South Sandwich Trench, 7-8, 13
space, molecules in, 17-18, 93-4
sparrow, American song, races of, 21,
s-p-d-f notation, 11-12*, 45, 46
special theory of relativity, 3, 15; 10,
       44-5, 48; 30, 5, 9, 32; 31*, 15,
       24, 27, 42; 32, 6, 7, 14, 38
speciation, 21*, 22, 23, 24–7; 26, 8 species, 21*, 23; 26, 3, 6, 8, 15
  abundance of, 19, 4, 5, 11; 21, 27
  classification, 21, 27-34
  new see speciation
specific heat (capacity), 9*, 25, 26, 29
specific rotation, 17-18*, 59
specificity, enzyme, 22, 25, 27
spectrometer, mass see mass
       spectrometer
spectrophotometry, absorption, 15,
        38
spectroscopy, 11-12, 47-51, 70-1;
        13-14, 74, 75
spectrum see absorption spectra;
       atomic spectra; continuous
        spectrum; electromagnetic
        spectrum; emission spectra;
        line spectra; mass spectrum;
        solar spectrum
speed, 3*, 5, 10
  instantaneous, 3, 5
   and kinetic energy, 9, 2, 16, 17-18,
        19; 17-18, 19
   molecular, 16, 20, 21
   of orbiting planets, 2, 36
   of waves, 5-6, 29-32, 33, 35, 36, 37,
        38, 60-8, 81; 10, 14, 16
   velocity and, 3, 5-6
speed of light in a vacuum, 2, 8; 10*, 38, 39; 31, 24, 27; 32, 4, 6, 7
spermatocytes, 20, 11, 12
sperm cell see gametes
sperms, 20*, 8, 17, 20, 28
   production of, 20, 11-12, 14-16,
        17, 25-6
   see also gametes
spherical avocado pear model, 5-6*,
        12, 60, 76
spherical geometry, 7-8, 55
spherical model of Earth, 1, 9, 12-15
spherical surface, 1, 13
spin of an object, 1*, 24
   axis of, 1, 24
   of Earth, 1, 27-8
   of Moon, 1, 38-9
spin of subatomic particles, 31, 12,
        21; 32, 13; see also electron
        spin
spinal cord, 23, 32, 33
spindle, 20*, 20, 49
spiracles, 23*, 8
split genes, 20, 50; 24*, 44, 46-7
spontaneous nuclear fission, 31*, 32,
SPS (Super Proton Synchrotron), 30,
        5: 32, 8, 40-1
stable isotopes, 31, 18-19, 25, 27
stability of noble gases, 13-14, 58
Stahl, Franklin W., 24, 19, 20, 50
standard deviation, 4*, 25, 26-7
standards of measurement, 2, 5-11
   of length, 2, 6-8
   of mass, 2, 9
   of time, 2, 8-9
```

standing waves, 30*, 18, 23 as wavefunctions, 30, 19-22 Stanford Linear Accelerator Centre see SLAC stars, 1*, 11, 13, 18, 40-1 nuclear fusion in, 31, 41 spectra of, 11-12, 71 temperature of, 11-12, 71 see also Sun starch, 22, 3, 17, 33-5, 37, Plate 6; 26, 10, 18 see also amylopectin; amylose starling (Sturnus vulgaris), 25, 4 statements, falsifiability of, 1, 7, 8, 10, statistical significance tests, 4, 17 statistics, manipulation of, 4, 13 stearic acid, 22*, 15, 16, 61 steel, spectroscopic analysis of, 11-12, 70 Steno, Nicolaus, 28-29, 14 step polymerization, 17-18, 82 stereoisomers/stereoisomerism, **17–18***, 42, 44, 45, 53–6, 95 see also geometric isomerism; optical isomerism sterility of hybrids, 21, 26 sterilization by radiation of screw-worm fly, 25, 55 stick insect, 19, 13, 15, 16 sting, 19, 13 stomach, 26, 10, 11, 18 stomata, 22*, 64, Plate 8 Stonehenge, 2, 4-5 stony-iron meteorite, 28-29*, 44, 45, 51 stony meteorite, 28-29*, 44, 51 stop codons, 24*, 29, 34, 37, 38, 39; 26, 17 stored energy, 23, 14 strain, 5-6*, 29, 30 and tectonic process, 27, 46 strain energy, 9*, 3, 5; 23, 14 strangeness, 32*, 22 conservation, 32, 22-3 of gauge bosons, 32, 22, 39 of hadrons, 32, 22, 23-4, 25 of leptons, 32, 22 non-conservation, 32, 24, 31, 36 of quarks, 32, 26, 31, 36 Strassmann, Fritz, 1, 5; 11-12, 22-3 strata, 28-29*, 11 horizontal, 28-29, 24 Stratigraphic Column, 28-29*, 4 calibrating, 28-29, 32-5 dating granite, 28-29, 34, 35 igneous rocks as calibration points, 28-29, 32-3, 35 subdividing Column, 28-29, 34-5 development of, 28-29, 14-25 examples, 28-29, 20-1 faunal succession, 28-29, 15-19, first attempt at, 28-29, 14-15 fossils in, 28-29, 11, 12, 13, 14, 18, 24, 25 and geological time estimates, 28-29, 25-6, 31 names of Periods, 28-29, 22-3 superposition, 28-29, 14, 25 uniformitarianism, 28-29, 19, 22, 25, 55 stratigraphic sequence, 28-29*, 11, 13

stratosphere: halocarbons and ozone layer, 17-18, 15-16 stratum see strata streamlining as adaptation, 19, 13 strength of an electrolyte, 15, 19 relative, of interactions, 32, 16, 29 stress, 5-6*, 29, 30 adrenalin release produced by, 23, stress and tectonic process, 27, 46-7 stretch receptors, 23*, 34, 35; 26, 18 striations, 27, Plate 9 string theories, 32, 44 stroboscopic determination of g_E , 3, stroke volume of heart, 23*, 16, 20, 33, 36, 37 stromatolites, 28-29*, 54, 58 strong acid, 15*, 18, 23, 26 strong base, 15*, 18 strong electrolyte, 15*, 18, 19, 20 strong interaction between hadrons, protons and neutrons in atomic nuclei, 31*, 19-20, 27 hadrons in general, 32, 4, 18 see also hadrons strong interaction between quarks, 32*, 4, 29, 30, 31 strontium isotopes, 28-29, 30, 36 in oceans, 28-29, 59-60 structural formulae, 17-18*, 8, 9, 10 and isomerism, 17-18, 25-35 structural genes, 24*, 42 structural isomers/isomerism, 17-18*, 25, 28, 29, 30-5, 53, 57 see also functional isomers: position isomers; skeletal isomers structural proteins, 22, 20 structure chemical, 13-14, 8 of DNA, 24, 9-13 and function, relationship between, 19, 13-14; 22, 20, 29; 23, 14, 21 styrene, 17-18, 41, 79 subclass, 21, 32 sub-cycles, ecological, 25, 21 subduction, 7–8*, 56, 69–70, 72, 78, 79 zones, 27, 24–7, 29, 52–3 sub-Groups A and B in the Periodic Table, 13-14*, 30, 33, 40 subkingdom, 21, 29, 32 sublimation, 16, 5 suborder, 21, 32 subphylum, 21, 31-2 subshells see electron shells subspecies, 21*, 29, 33 see also races substitution (of a base) see mutation under bases substrates, 22*, 25, 26-7, 30, 31; 26, 10 substrate level phosphorylation, 22*, 49, 53, 54 succession, 25*, 60, 62 successive ionization energies, 11-12*, 37, 38 succinic acid, 22, 45 sucrose, 22, 17, 43 sugar cane used for ethanol

production, 25, 11

sugars, 17-18, 93; 22*, 7, 17, 64; 26, in blood, level of, see diabetes in DNA see deoxyribose in RNA see ribose in seeds, 24, 42 see also carbohydrates; disaccharides; glucose; monosaccharides; sucrose sulphates, 22, 9, 14, 64; 28-29, 60, 61 sulphides in Earth's core, 28-29, 42, 49 in meteorites, 28-29, 44-45 sulphur, 11-12, 5, 22, 64; 28-29, 57 chemical bonding, 13-14, 65, 66 cycle, 25, 31-2 in Earth's core, 5-6, 75-6, 80, 81; 28-29, 49 in meteorites, 28-29, 43, 45 in oceans, 28-29, 59, 60, 61 in rocks, 27, 6 sources of, in living organisms, 22 8-9, 14, 64 sulphur dioxide in atmosphere, 25, 31, 32; 28-29, 52, 55, 56, 57, 58, 60 as pollutant, 15, 31-3 as refrigerant, 17-18, 14 sulphur trioxide, 15, 31 sulphuric acid, 17-18, 71 in acid rain, 25, 30 Sun apparent size of, 1, 17, 22, 24 composition of, 28-29, 45-6, 48 core of, 31, 39 Earth and, 1, 17, 34, 37, 38, 43, 45 eclipse of, 1, 37-8; 2, 28-9 energy from, 9, 5-6, 12; 10, 4, 53; 22, 38; 25, 7-8; 26, 18; 28-29, 64, 70, 71, 72 sunspot cycles, 28-29, 77-8 as focus of planetary orbits, 2, 30-1, 36 measuring distance to, 2, 26-8, 29 radius of, 2, 28-9 neutrinos, 32, 14, 16, 43, 44 nuclear fusion in, 31, 39 observation of, 1, 7, 8, 11-12, 14, 17, 25 and origin of Solar System, 28-29, 37 - 41particles emitted, 32, 14, 16, 44 radiation, 25, 7-8, 20; 26, 12 aquatic environment and, 25, 16-17 carbon cycle and, 25, 25 production ecology and, 25, 7-8, 9, 15, 18 ultraviolet radiation, 28-29, 54, 55, 62-3, 65, 67, 70 see also solar sunspot cycles, 28-29*, 77, 78 Super Proton Synchrotron see SPS superconductivity, 13-14, 40; 30, 34 superfamily, 21, 31, 32 superposition, principle of (Earth sciences), 28-29, 14, 25 superposition of waves, 10*, 17, 18-24, 26, 28-35, 37 different amplitude, 10, 22-3 principle of, 10, 17, 18-24, 25 see also constructive; destructive surface features of Earth, 7-8, 8-11, 15 surface waves, 5-6, 90 survival, 19, 32; 22, 3-5, 12-13 adaptation and, 19, 15-20 fecundity and viability, 19, 20, 21 - 3of proteins, 22, 6, 7, 38, 40 and turnover of all compounds, 22, value, 19, 33-4 see also biosynthesis; fitness; growth survivorship curve, 25*, 38, 55 suspended load, 27*, 35, 36-7, 44-5 S-waves, 5-6*, 28, 33, 38, 75, 78, 90 speed of, 5-6, 31-2, 61-4, 65, 67, 68, 81 S-wave shadow zone, 5-6*, 63, 65 Swift, Jonathan, 1, 9-10; 5-6, 40 swingboat, energy conversions in, 9, 14, 15, 18-19, 23 Syene (Aswan), in size of Earth measurement, 2, 15-16, 18-20 Sykes, Lynn, 7-8, 56, 81 symbolizing particles, 32, 13, 18 symbols, mathematical, meaning of, 2, 12 sympathetic nervous system, 23*, 34, 37; 26, 11 synchrotrons, 32*, 8, 9, 40-1 synthesis of cellular compounds, 19*, 10, 11; 22, 5, 62-4 see also biosynthesis; protein synthesis synthetic RNA polymers, 24, 36, 37, 38 synthetics, 17-18, 4 see also fibres; giant molecules; polymerization systematic errors, 3*, 25, 26; 4, 18-19 Système Internationale d'Unités see SI units systemic circulation, 23*, 13, 14, 20, 34

T

T see tesla; thymine T, virus, 24, 5-6 tables of data, compiling, 4, 8, 9 tailoring and splicing, 24*, 44, 45 tangent (tan), 2*, 32 tangent to a circle, 2*, 31 tape-worm; oxygen supply, 23, 6 target tissue, 23*, 26, 28 tasters and non-tasters, 21, 11 tau, τ, see half-life under radioactive decay τ lepton, 32, 34-5, 37, 43 taxonomic hierarchy, 21*, 27, 29-32 taxonomy, 21*, 27 TCA cycle see tricarboxylic acid cycle tectonics, 7-8*, 4 processes, 27, 4, 5, 46-9 see also compression; tension see also plate tectonic theory Teflon, 17-18, 79 teleological statements, 23*, 14, 21 telophase in meiosis, 20, 13, 15, 16, 21, 29, 34, 37; 26, 15 compared with mitosis, 20, 47, 48 temperature, 9, 23-5, 26, 27-9; 26, 10, 18 boiling, 17-18, 11, 22, 57, 62 ionic substances and, 13-14, 51, 57, 69, 72 climatic, 28-29, 70, 72-3, 75, 77, 79 see also ice ages constant in endothermic and exothermic reactions, 16, 4, 6 control of internal, 23, 23-4, 30-1 in central heating systems, 23, 28-9 enzymes and, 22, 28-9 equilibrium yield of ammonia and, 16, 31-2 global, rise in, 25, 25, 31 growing seasons and, 25, 9-10 of interior of Earth, 5-6, 7-8, 22, 67; 27, 4, 18-19, 29; 28-29, 26, 57 and magnetism, 5-6, 56, 57-8 in living organisms, 22, 10, 11, 65 melting, 17-18, 11, 84; 27, 19, 24; 28-29, 49, 50 ionic substances and, 13-14, 51, 57, 69, 72 molecular interpretation of effect, 16, 20-1of ocean surface water, 28-29, 75 rate of chemical reactions and, 16, 18, 19, 21, 27, 28, 29 rocks and crystallization, 27, 10-11, 16 frost-shattering, 27, 31-2, 34, 44 increases with depth, 27, 51-2 melting, 27, 19, 24 at plate margins, 27, 25 primordial heat, 27, 19, 29 and tectonic process, 27, 46-7, 51-2, 54and solubility of oxygen in water, 23, 5 see also heat template, 24, 17 tension, structures produced under, 27, 46, 47-8 termites, 19, 5 terrane, 7-8*, 74, 75 tertiary alcohols, 17-18*, 72 Tertiary Period, 28-29, 14-15, 23, 68, fossils in, 28-29, 12, 68, 70 ocean current in, 28-29, 77 Terylene, 17-18, 82, 87 tesla, T, 5-6*, 49, 51 testing statements, 1, 7, 8, 10 tetanus, 22, 57 Tethys Ocean, 7-8, 25 tetrafluoroethylene, 17-18, 79 tetrahedron carbon atom as, 17-18, 25, 52-3 silicate unit as, **27**, 7–8, 16 textiles see fibres texture of a rock, 5-6*, 8, 9; 27*, 48 Thalidomide, 17-18, 5 Thames, River, ecosystem in, 25, 16-17 theory, 1, 8 therm, 9, 12 thermal denaturation, 22*, 28, 29 thermal gradient, 27*, 51 thermometers, 9, 23-4 thermonuclear weapons, 9, 5

thermophilic bacteria, 22, 29 thermoplastic polymers, 17-18, 84 thermoregulatory systems see temperature control thermosetting polymers, 17-18, 84 thionyl chloride, 17-18, 64, 67, 74 Thomson, G. P., 30, 11, 12 Thomson, J. J., 11-12, 66, 68-9; 30, 10, 11, 12; 32, 13 thorium isotopes, 28-29, 50 thought experiment, 1*, 19 three-dimensional motion, 30*, 25 threonine (Thr), 22, 21; 24, 36 threshold frequency (for photoelectric effect), 10*, 43, 44, 47 thrust, 27*, 48, 54 thymine (T), 17-18, 89; 24*, 10, 11-12 tidal friction, 7-8, 23 'tidal waves' (tsunamis), 5-6, 13 tides, 1, 12 till, glacial, 7-8*, 56; 28-29, 74, 79, Plates 1 and 2 achromatic, 22, 33, 37 geological, absolute measurement of, 28-29, 25-31 early estimates, 28-29, 25-6 radiometric 'clocks', 28-29, 26-31 ordering events in, 28-29, 5-13 fossils and evolution, 28-29, 12, 63-70 varves, 28-29, 7-8 standards of, 2, 8-9 see also age of Earth; dating tin, 13-14, 69 in alloy, 13-14, 69, 74 combination with iodine, determining formula, 13-14, 10, 11-14 in rocks, 27, 6, 37 Ting, Samuel, 32, 32, 34 tissues, 19*, 5; 23, 19, 22, 24, 26, 28 titanium, 13-14, 28, 29, 31-2, 37-9 in oceans, 28-29, 59 in rocks, 27, 21, 22-3; 28-29, 46 toad, nuclear transfer experiments with, 24, 15-16, 50 Tomonaga, Sin-Itiro, 10, 52 topness, 32*, 36 total generation pre-reproductive mortality, k_{total} , 25*, 40, 41, 55 total reflection, 5–6*, 35 'trace elements', 25, 21 trachea, 23, 9, 10 tracheal system, 23*, 8, 10 transcription, 24*, 24, 25-6, 42 manufacture of protein and, 24, 44, 46-7 transducer, energy, 22, 11-12 see also ADP; ATP Transeau, Edgar, 25, 8-9 transfer of heat see under heat nuclear, 24, 15, 16, 50 transfer RNA (tRNA), 24*, 23, 42, 45; 26, 8, 17 anticodons, 24, 31, 32, 33 genetic code and, 24, 35, 37, 38 role of, 24, 31-2, 33 transform faults, 7-8*, 51, 52, 54, 56, 58, 59 plate margins and, 7-8, 64, 73-4,

transformation, bacterial, 24, 5 trans isomer, 17-18*, 44, 45, 48, 49, 51, 73 transition atomic, 31, 3-4, 13-14 y-decay as nuclear, 31, 31 transitions, phase, 16, 5, 6, 16 transition elements, 13-14*, 37, limits, 4, 22, 23 39-40, 41 quoting, 4, 21 transition zone, 5–6*, 66, 68, 81 translation, 24*, 27, 28–32, 33, 34 manufacture of protein and, 24, 44, 45, 46-7 mRNA makes protein, 24, 27-31 tRNA, role of in, 24, 31-2, 33 translational motion of objects, etc., principle 9.17 transport proteins, 22, 20 transportation of eroded and weathered material, 27, 34-7, 31, 40 39-41, 44-5, 53, Plate 14; 28-29, 5, 19, 22, 60, 61 transposable elements, 20, 50 transverse wave motion, 5-6*, 27, 28; 10, 10-16 see also S-waves travel times see seismic waves, speeds trenches see oceans triangles, angles of, 2, 27, 32 Triassic Period fossils in, 28-29, 12 of measurement in Stratigraphic Column, 28-29, natural, 2, 7, 8 20-1, 23 prefixes to, 2, 11 SI, 2, 6, 7-9, 11 tricarboxylic acid cycle (TCA cycle), 22*, 44, 45, 46, 47, 49-51, 54, trichlorides, 13-14, 57, 60, 76 38, 46, 49 1,1,1-trichloroethane, 17-18, 23 Universe, 1*, 14 triglycerides, 22*, 16 see also fats; fatty acids; glycerol trigonometry, 2, 32 trilobites, 28-29*, 9, 10, 67, 68, 70, regularity in, 1, 18 Plate 30 triple bonds, 13-14*, 61, 62; 17-18*, see also unsaturated compounds triplet code, 24*, 29, 35, 36, 37-8 tRNA see transfer RNA tRNA anticodon, 24*, 31, 32, 33 trisaccharides, 22, 17 trolley and spring experiment, 3, 12 - 13trophic levels, 25*, 11, 12, 13, 14, 15, 18 trough of a wave, 10*, 11 truth see topness truthfulness of scientists, 1, 6, 10 Y particle, 32, 36-7 tryptophan (Trp), 22, 21; 24, 36, 37 tsunamis, 5-6*, 13 uracil (U), 24*, 24 tubulin (protein), 20, 20 tungsten, 11-12, 4, 5, 6 turnover, 22*, 5 13-14, 39, 41 turntable, rotation of, 1, 18-19, 23 two-dimensional motion, 30*, 24, 25 42, 50 two-slit diffraction, see double-slit nucleus typical elements, 13-14*, 36 tyrosine (Tyr), 22, 21; 24, 36 32 - 3, 36

U

U see uracil ultraviolet radiation, 10, 40, 53; 28-29, 54, 55, 62-3, 65, 67, 70

ozone layer as shield against, 17-18, 15; 28-29, 54, 55 unbound electron, 11-12*, 40 uncertainties, 2*, 20; 3, 26, 31; 4, 18 estimating, 4, 19-20 graphical representation of, 4, 22-3 identifying, 4, 16-17 random, 3, 25; 4, 18, 19-20 see also systematic error uncertainty in a quantum mechanical measurement, 30*, 26, 27, 30 uncertainty principle see Heisenberg's uncertainty unconformity, 28-29*, 16, 17, 18, 34, Plates 28 and 29 uncontrolled nuclear chain reaction, undissociated acid, 15, 22 unicellular organisms see single-celled unified theory of electromagnetic and weak interactions, 32, 40-1 uniform magnetic field, 11-12, 53 uniformitarianism, principle of, 27, 53-4; 28-29, 19, 22, 25, 66 of energy, 9, 11-12, 13 and mass, 32, 7, 12 universal constant, 3*, 35 universal nature of genetic code, 24, evolution of, 32, 44-5 geocentric model of, 1, 14 origins of, 9, 6; see also Big Bang unpaired electrons, 11-12*, 55, 60 unpolarized light, 17-18, 57 unsaturated compounds/unsaturation (double and triple bonds), 17-18*, 37, 38, 39-52, 78 geometric isomerism, 17-18, 46-51 structure of, 17-18, 37-41 unstable isotopes, 31, 18, 25, 27, created by nuclear fission, 31, 38 see also radioactive decay Updike, John, 32, 17, 47 upper and lower limits, 2*, 20 upper mantle, 5-6*, 66, 68, 81 up (u) quarks, 32, 26-30, 36, 43 **uraninite**, **28–29***, 53, 59 uranium, **11–12**, 5, 13, 18–19, 22, 23; isotopes, 28-29, 27, 30, 31, 36, 37, and nuclear fission, 31, 37-8 radioactive decay of, 31, 28-9, used in nuclear power stations, 31, 40 in rocks, 27, 6; 28-29, 53, 60 Uranus, 28-29, 38-9, 41

orbit of, 2, 34, 40

urea, 22, 61; 23*, 23, 26

uric acid, **22**, 61; **23**, 23 urine, **23**, 23, 24, 25, 26

V

vacuum acceleration due to gravity in, 3, 19, 39 electromagnetic waves in, 10, 39-40, 41 speed of light in, 2, 8; 10, 38-9; 31, 24, 27 valency, 13-14*, 21, 22, 23-5, 76 of elements in carbon compounds, 17-18, 9, 10 maximum, 13-14, 27 and molecular covalent substances, 13-14, 60-1 valine (Val), 22, 21; 24, 36, 37, 40, 41; 26, 9, 18 vanadium, 13-14, 37-9 van der Meer, Simon, 32, 41 variables, independent and dependent, 4, 11, 24 variation discontinuous, 20, 4 see also genetic variability; speciation varves, 28–29*, 7, 8, 13 vegetation see plants vein, 23*, 12, 13, 14, 19-20 hepatic portal, 23, 25 pulmonary, 23, 13, Plate 9 velocity, 3*, 5, 6, 7 components of, 30, 24, 25, 26 constant, 3, 9 momentum and, 3, 15-17 rate of change of, 3, 6-7 speed and, 3, 5-6 velocity of seismic waves, 5-6, 30, 64 Vema Fracture Zone, 7-8, 51 vena cava, 23*, 13, Plate 9 ventricles, 23*, 12, 13, 14, 34, Plate 9 Venus, **28–29**, 38–9, 41, 47, 48 orbit of, **2**, 30–2, 36, 38, 40 Vernier scale, 4, 5 vertebrates, 21, 31-2; 28-29, 11-12, 67, 68 genetic variability, 21, 13, 14, 15 vesicular (frothy) basalt, 5-6*, 8 viability, 19*, 21, 23, 24, 32 Vine, Professor Fred, 7-8, 43-4, 45, 46, 52, 58, 80, 81 vinegar, 15, 5, 6, 31 see also acetic acid Vine-Matthews hypothesis, 7-8*, 44, 46, 52, 58, 81 vinyl chloride, 17-18, 79 viruses, 19, 9, 10, 11 diseases and, 19, 3, 9 evidence for role of DNA from, 24, 5, 6-7 T₂ virus, structure of, 24, 6 viscosity, 23*, 20, 21, 27, 19 visible light, 10*, 39, 40-1, 48 visualizations of atom, 30, 30-1 vitamins, 17-18, 21; 22*, 31, 32 volcanic activity, 7-8, 12, 15, 16, 39 carbon cycle and, 25, 23, 24 gases in atmosphere, 28-29, 55-6, plate margins and, 7-8, 63, 64, 65,

66-71, 74, 78, 79

VOLCANIC ROCKS ZYGOTE

volcanic activity (continued) see also igneous; seismic volcanic rocks see extrusive rocks volcanoes, 5-6, 7, 8, 67, 68, 77, Plates 20a, 20b; 27, 19-20, 52-3, Plate 11; 28-29, 50 cone, 27, 20, 28 eruptions, 27, 19, 20, 25, 26, 27, Plate 10; 28-29, 22, 60, 61 atmospheric gases from, 28-29, 55-6, 57, 58, 60, 61 dust and climate, 28-29, 78 and island arcs, 27, 25, 27, 28 shield, 27, 19, 29 volt, 9*, 33, 35 voltage difference, 9*, 33, 35 volumes, measuring, 4, 6 voluntary control of breathing, 23, 33 Von Humboldt, Karl, 7-8, 17 Voyager missions, 5-6, 6

W

Wadati-Benioff zone, 7-8*, 35, 36, 56, 58, 69, 70, 81 Wallace, Alfred Russel, 19, 12, 15, 32, 37; 20, 31 wander paths, apparent polar, 7-8, Warfarin (rat poison), rats' resistance to, 21, 9, 10 wasps, 19, 5, 12 see also gall wasp; parasitic wasps water, 13-14, 42-3, 60 biogeochemical cycles and, 25, 25, 30, 32 chemical bonding, 13-14, 57, 60, 61 cycle, 25, 31 deposition in, 27, 35, 36, 38 electronegativity, 13-14, 67, 68 hydrological cycle, 25, 21; 27, 4, 53 ion product of, 15, 25-7, 33 life in, 28-29, 54-5, 57, 58, 61, 66, 69 loss, 23, 26 meteoric, 28-29, 55 as molecular covalent substance, 13-14, 53, 56 oxygen diffused in, 23, 5, 7, 8, 9, 10, 35 pH of, 15, 29, 30 phases of, 13-14, 19 photochemical dissociation of, **28–29**, 55, 57, 60 polluted, 25, 27, 29, 30-1, 32 as product of metabolism, removing, 23, 22-3, 24 sediments transported by, 28-29, 60, 61 transport by, 27, 34-7, 44-5 vapour in atmosphere, 28-29, 55, 56, 57 and vegetation types, 25, 10 waves, 5-6, 23-4; 10, 4-7, 11, 12, 25-6, 40, 41 weathering by, 27, 31, 32, 34, 40, 44 see also aquatic; aqueous; hydrological cycle; oceans water fleas (Daphnia), 25, 16 Watson, James, 24, 3, 10, 12 Watt, James, 9, 34

wave, 5-6, 23-4; 10, 4-7, 11, 12, 25-6, 40, 41 action, 27, 36 amplitude of, 5-6, 23; 10, 11, 16, 20, 22-3, 24 circular, 10, 25, 30, 33 crest of, 10, 11 diffraction of, 10, 6-7, 25-6 frequency of, 10, 13, 16, 23 of electromagnetic radiation, 10, 3, 4-7, 10-16, 44; 30, 6-7 of matter, 30, 10-12, 13, 14, 15-17 see also diffraction motion compressional, 5-6, 25 transverse, 5-6, 27-8 period of, 10, 13, 16, 23 plane, 10, 25-6, 30, 33 quanta behaving as, 30, 12, 13, 17 reflection of, 10, 4, 5 refraction of, 10, 4, 6 representations of, 10, 14, 16, 23-4 speed of, 10, 14, 16 standing, 30, 18-23 surface, 5-6, 90 transportation of sediments, 27, 36-7 trough of, 10, 11 see also electromagnetic waves; seismic waves; superposition; wavefront; wavelength; wave-particle and under speed wavefront, 10*, 25 wavefunctions, 30*, 17-22, 23, 32; 31, 5-7,9 infinite sine waves as, 30, 19, 21, 22 interpreting, 30, 19 of atomic electron, 30, 31 standing waves as, 30, 19-22 types of, 30, 19 wavelengths, 5-6*, 24; 10*, 11, 16, 23 of electromagnetic radiation, 10, 35-6, 39-41; 30, 6-7 of light, 2, 7 of matter, 30, 10-11, 21 quantization of, 31, 5-7, 9-10 see also de Broglie's formula wave-particle duality of electromagnetic radiation, 10*, 3, 51–2, 53, 54; 30, 6–9, 12 of matter, 30*, 12 weak acid, 15*, 19, 20, 24 chemical equilibrium in, 15, 18-20 weak bonds, 22*, 23, 29 weak electrolyte, 15*, 19 weak interaction, 32*, 4, 16 mediated by gauge bosons, 32, 38, 39, 40-1 hadrons, 32, 18-19 leptons, 32, 16, 35 quarks, 32, 28, 29 weathering, 25, 23; 27*, 31, 53, Plate 14 chemical, 27, 31-4, 44 physical, 27, 16, 31-2, 44 products of, 28-29, 60, 61 resistance of minerals to, 27, 32, 33, 44 see also erosion; transportation Wegener, Alfred, 7-8, 17, 27, 57, 80,

continental drift theory

evidence for, 7-8, 18-23, 26 mechanism for, 7-8, 23 reaction to, 7-8, 23-6 weight, 3*, 20, 21, 23 Weinberg, Steven, 32, 40, 41, 42, 45 Weinberg-Salam theory, 32*, 30, 40, 41, 42 Werner, Alfred, 13-14, 33, 40 white blood cells, 23*, 18, 20, Plate 10 white light, 10*, 36 spectrum, 11-12, 25, 26 whitefly (Trialeurodes vaporariorum), 25, 54 Widmanstätten patterns, 28-29*, 43, Wien, Wilhelm, 30, 28 Wilkins, Maurice, 24, 10 Wilson, Tuzo, 7-8, 44, 51-2, 58, 81 wind, erosion, transport and deposition by, 27, 39-40, 44, 45 wobble hypothesis, 24*, 37, 38 woodlands see forests work function, 10*, 46, 47 W particles, 32, 40-1 written reports and records, 1, 6; 4, 7-8, 27-34 Wytham Wood, owls in, 25, 36-43

X

xenon, 13–14, 28, 31, 38–9, 58 in atmosphere, 28–29, 52, 57 photoelectron spectrum, 11–12, 41 Xenopus see toad X-rays, 10, 40, 49; 30, 6; 31, 16, 34; 32, 16 crystallography, 17–18, 84, 87 diffraction of, 30, 12

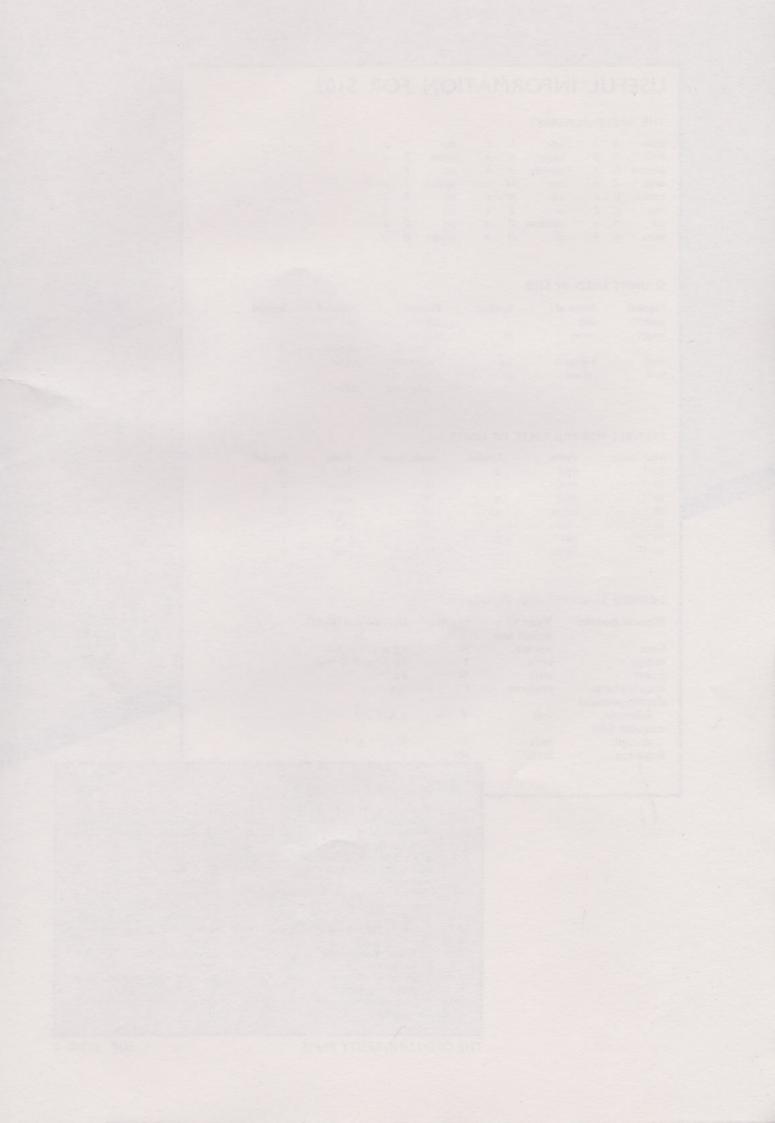
Y

year, solar, 1, 22 yeast, **24**, 14 anaerobic catabolism in, **22**, 57, 58

Z

Zeeman effect, 11-12*, 56, 57 zero, absolute, 9, 24, 28 Ziegler, Karl, 17-18, 80, 85, 96 zinc, 13-14, 37-9 in rocks, 27, 6 zinc chloride, 13-14, 21 zinc oxide, 13-14, 14-15 zircon, 28-29, 31, 36, 37 zonation, 25*, 57, 58, 62 zones, 28-29*, 24 zooplankton, 25*, 5, 16-17; 26, 12, 13, 18, 19 see also plankton Z particle, 32, 40-1 Zweig, George, 32, 26, 28, 31 zygote, 20*, 11, 17, 45, 49; 21, 14; 22, 3, 4, 7; 24, 4-5, 8, 15 see also heterozygosity; homozygous

watt, 9*, 34, 35



USEFUL INFORMATION FOR \$102

THE GREEK ALPHABET

alpha	A	α	iota	I	1	rho	P	P
beta	В	β	kappa	K	K	sigma	Σ	σ
gamma	Γ	γ	lambda	1	λ	tau	T	τ
delta	4	δ	mu	M	μ	upsilon	Y	D
epsilon	E	3	nu	N	v	phi	Φ	φ
zeta	Z	5	xi	Ξ	ξ	chi	X	χ
eta	H	η	omicron	0	0	psi	Ψ	Ψ
theta	Θ	θ	pi	П	π	omega	Ω	w

SI UNITS USED IN S102

Physical quantity	Name of unit	Symbol	Physical quantity	Name of unit	Symbol
length	metre	m	electric	ampere	A
mass	kilogram	kg	temperature	kelvin	K
time	second	S	amount of substance	mole	mol

PREFIXES FOR MULTIPLES OF UNITS

Mult. factor	Prefix	Symbol	Mult. factor	Prefix	Symbol
10-1	deci	d	10 ¹	deca	da
10-2	centi	С	10 ²	hecto	h
10-3	milli	m	10 ³	kilo	k
10-6	micro	μ	10 ⁶	mega	M
10-9	nano	n	109	giga	G
10-12	pico	p	1012	tera	T
10-15	femto	ſ	1015	peta	P

DERIVED SI UNITS USED IN S102

Physical quantity	Name of derived unit	Symbol	Derived unit (in SI)
force	newton	N	$kg m s^{-2} = J m^{-1}$
energy	joule .	J	$kg m^2 s^{-2} = N m$
power	watt	W	J s - 1
electric charge electric potential	coulomb	С	A s
difference magnetic field	volt	V	J A ⁻¹ s ⁻¹
strength	tesla	T	$N m^{-1} A^{-1}$
frequency	hertz	Hz	s ⁻¹

SIO2 UNITS

1	Science and the planet Earth	19	Life and evolution
2	Measuring the Solar System	20	Inheritance and cell division
3	Motion under gravity	21	Genes and evolution
4	Practical work in science	22	Biochemistry
5-6	Into the Earth: earthquakes.	23	Physiology
	seismology and the Earth's magnetism	24	DNA: molecular aspects of genetics
7-8	Plate tectonics: a revolution in	25	Ecology
	the Earth sciences	26	Biology reviewed
9	Energy	27	Earth materials and processes
10	Modelling the behaviour of light Atomic structure	28-29	Geological time and Earth history
13–14	Chemical reactions and the Periodic Table	30	Quantum mechanics: an introduction
15	Chemical equilibrium	31	Quantum mechanics: atoms and
16	Chemical energetics		nuclei
17-18	The chemistry of carbon compounds	32	The search for fundamental particles